Economic Geography and its Effect on the Development of the German States from the Holy Roman Empire to the German Zollverein
(Wirtschaftsgeographie und ihr Einfluss auf die Entwicklung der deutschen Staaten vom Heiligen Römischen Reich bis zum Deutschen Zollverein)

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Zusammenfassung

Die vorliegende Dissertation setzt sich mit dem Einfluß ökonomischer Geographie auf die Geschichte des Heiligen Römischen Reichs deutscher Nation bis zum Deutschen Zollverein auseinander. Die Dissertation besteht aus drei Kapiteln. Im ersten Kapitel werden die Effekte von Heterogenität in der Beobachtbarkeit der Bodenqualität auf Besteuerung und politischen Institutionen erläutert, theoretisch betrachtet und empirisch anhand von Kartendaten analysiert. Es wird ein statistischer Zusammenhang zwischen Beobachtbarkeit der Bodenqualität und Größe und Überlebenswahrschenlichkeit von mittelalterlichen Staaten hergestelt. Das zweite Kapitel befasst sich mit dem Einfluß dieses Mechanismus auf die spezielle Geschichte Brandenburg-Preußens, und erläutert die Rolle der Beobachtbarkeut der Bodenqualität auf die Entwicklung zentraler Institutionen nach dem Dreißigjährigen Krieg. Im empirischen Teil wird anhand von Daten zu Provinzkontributionen ein statistisch signifikanter Zusammenhang zwischen Bodenqualität und Besteuerug erst im Laufe des siebzehnten Jahrhundert deutlich. Das dritte Kapitel befasst sich mit dem Einfluß relativer Geographie auf die Gründung des Deutschen Zollvereins als Folge des Wiener Kongresses. Durch Analyse der Handelsströme und potentieller Zolleinnahmen wird ein Zusammenhang zwischen Geographischer Lage und der Entscheidung, dem Zollverein anzugehören deutlich. Dies erklärt in Teilen, wie einnahmemaximierende Staaten dem Zollverein aus Eigeninteresse beitreten konnten.

Summary

This dissertation features three essays on the influence of Economic Geography on the development of the Holy Roman Empire until the German Zollverein. The dissertation consists of three essays. The first analyzes the effect of geographically induced heterogeneity of soil quality, which has knock on effects on the development of taxation and political institutions. These ideas are analyzed both theoretically and empirically, using a novel dataset of GIS maps. Results indicate a relationship between observability and states' geographic sizes and survival probability. The second chapter employs these ideas in the context of Brandenburg-Prussia, striving to create a centralized state after the Thirty Years War. Empirics indicate a relationship between observability and provincial contribution during the decades following the Thirty Years War. The third chapter analyzes the influence of geography on the foundation of the German Zollverein as a consequence of the Congress of Vienna. By analyzing trade flows and potential tariff revenues, a relationship between a state's geographic location and its decision to join the Zollverein is revealed. In parts, this explains how revenue-maximizing states could join the Zollverein, for their own interest.

Contents

Questioning Germany's role in the history of the European continent always provokes the study of the roots of its development. Its past, becoming out of hundreds of independent states, it's late unification under Prussian rule, the ubiquitous heritage of its totalitarian regimes, all these events are already enough motivation to carefully examine its past. Germany is by some both viewed as a dividing force, for many aspects held responsible for other European states' inability to take reasonable steps to solve the recent economic crisis. To some, Germany is a unifying element on the continent, and an element of stability, and a driver of European integration. To others, it is a stronghold of democracy against the New Populism spreading in other parts of Europe and the world.

Recent developments in the theoretical study of economic collaboration, the theory of incomplete contracts, and the study of the role of geography and transport for the modern economy, can not only be confronted with empirical tests but also conceptually extended in the context of German history.

It is the privilege of economic history, the 'big picture' discipline translating between other fields of economics, to connect between theory on the individual collaborating under asymmetric information, economic geography, the development of the state, and the emergence of today's pattern of international trade.

Therefore, this dissertation contains three essays that study the development of the state in and around modern Germany. Arranged in order of historical chronology, the they thrive to connect all the above questions, to better understand the origins of states in general and the German state in particular.

The first essay **"Lord of the Lemons: Origins and Dynamics of State Capacity" (page)** is joint work with Fabian Wahl of University of Hohenheim and aims to explain the roots of state development in the Holy Roman Empire 1250–1789. It employs a micro-economic model of incomplete contracts to understand how small spatial variation in in the quality of geography, more concretely the soil, allowed some states to tax agricultural output efficiently, and therefore thrive in competition with other states. This paper introduces the idea of institutional competition to the theory of transparency, or observability, of agricultural output. It proposes a new geographical index to test this idea empirically, and includes a new data set on the states in

the Holy Roman Empire. The model is tested using various measurements of state capacity.

To further provide evidence for the role of geography for efficient taxation, the second essay **"The State Built on Sandy Grounds: How Geography formed Brandenburg-Prussia" (page)** studies only one country in the Holy Roman Empire at the historical turning point at which it develops its efficient state, just after the Thirty Years War (1618–1648). In its attempt to link historical literature on Brandenburg-Prussia and incomplete contract theory, it analyzes the chronology of administrative reforms undertaken by the Hohenzollern rulers to efficiently tax its provinces outside of Brandenburg, overcoming the resistance of local elites. The paper argues that these administrative reforms were made possible by an advantageous geography of the Brandenburg soil. During the second half of the 17^{th} century, the Hohenzollern administration learned how to export this advantage to its other regions, most importantly to its territories in the West of today's Germany.

The combination of the Brandenburg-Prussian's ability to integrate their territories at the Rhine and historic circumstances allowed them to lead the economic integration of Germany, via the first customs union in history, the German Zollverein. To make this point, the third essay **"How Britain Unified Germany: Endogenous Geography and the Formation of a Customs Union" (page)**, which is joint with Nikolaus Wolf, offers a theory on the role of geography for the foundation of a customs union. This theory assumes that state rulers, at the foundation period after the Congress of Vienna, were revenue (not welfare) maximizing, and were dependent on transit tariffs for their state households. State rulers take into consideration their relative geographic size and position and compare it to the relative size and position of a customs union they could potentially join. As such, this paper introduces the problem of multiple marginalization into the literature on customs unions, and understands state collaboration as a mechanism to collect tariff revenue more efficiently. This model is then calibrated and tested using a simulation approach. This tests whether the sequence in which key states joined the customs union can be explained by revenue maximization. A counterfactual reveals that Prussia's control over the Rhine was a sine qua non condition for the formation of the German Zollverein under Berlin's rule, the economic predecessor of the German political unification.

Berlin, in December 2017

*Lord of the Lemons: Origins and Dynamics of State Capacity**

Thilo R. Huning† and Fabian Wahl‡

Abstract

To better understand the role of taxation in the emergence of states, this article presents an incomplete contract model of an agricultural society in which information asymmetries cause inefficient taxation, and hence outmigration, uprisings, and rent-seeking, but also urbanization. We propose a geographic index of information costs, observability, to test our model. Our case study is the Holy Roman Empire, which had a relatively homogeneous institutional framework, state of technology, culture, and ethnic composition across hundreds of observed states, for over 500 years. We find a robust link between observability and states' tax capacity, their size, and their survival.

JEL Codes: *D02 · D82 · H11 · H21 · N93*

Keywords: *State capacity · principal-agent problem · taxation · Holy Roman Empire*

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What creates a successful state? Current economic debate has stressed the role of efficient taxation and administration.[1] Despite disagreements about the role of the state for economic development, there is consensus that some level of state capacity is essential to ensure basic public good provision (Acemoglu, 2005). There is debate about what allowed some states to establish this capacity while others failed. Long-run studies point at the the self-reinforcing nature of state capacity[2], and have identified important structural changes around and after 1500, from the 'military revolution' to the Industrial Revolution until the emergence of the welfare state[3], all of which radically changed the rules of development. When searching for the optimal point in history to study the development of state finances, one has to study the period from just before until just after these structural changes, in order to avoid going back too far in time.[4] In this paper, we will trace hundreds of uniquely homogeneous states that were arranged in a federation, the Holy Roman Empire (HRE), through these radical changes, 1250–1789. We find evidence for a mechanism that links observability of (taxable) agricultural output to state capacity. This mechanism explains differences in state development during the medieval period, but not afterwards.

Our argument is based on the idea that states emerged when there was agricultural output that needed to be protected (see Bates et al. (2002); North et al. (2009) and more recently Dal Bó et al. (2015); Boix (2015); Mayshar et al. (2015)). Some believe states emerged from tribal societies realizing that security could be provided more efficiently in a central way (Bean, 1973). Tribal societies therefore set-up a voluntary 'social contract' (Rousseau, Hobbes) between the group and a 'violence specialist' (North et al., 2009, p. 20) who was granted the 'monopoly of violence'

[1] For modern examples and literature review, see Olsson and Hansson (2011). For historical overviews, see Dincecco and Prado (2012); Johnson and Koyama (2017) and (Dincecco, 2015).

[2] Examples include Allen (2009); Findlay and O'Rourke (2009); Mokyr (2011); Dincecco (2015); Karaman and Pamuk (2013); Ang (2015)

[3] These revolutions include the military revolution (Tilly, 1993; Diamond, 1999; Simms, 2013; Gennaioli and Voth, 2015; Boix, 2015), urban revolution (Allen, 2009; Bosker et al., 2013; Voigtländer and Voth, 2013; Karaman and Pamuk, 2013; Boix, 2015; Abramson, 2017), the discovery of the Americas (Hoffman, 2011; Nunn and Qian, 2011; Simms, 2013; Hoffman, 2015), the printing press (Rubin, 2014; Dittmar and Seabold, 2015), the Reformation (Cantoni, 2012; Cantoni et al., 2016; Dittmar and Meisenzahl, 2017), the Enlightment (Mokyr, 2011), the Financial Revolution (Neal, 2015), the French Revolution and its consequences (Acemoglu et al., 2011; Boix, 2015), nationalism (Anderson, 1983), and the expansion of public good provision in general (Alesina and Spolaore, 1997; Bolton and Roland, 1997; Alesina et al., 1999; Goldin and Katz, 2009).

[4] The few studies concerned with the determinants of state capacity prior to 1500 AD are primarily those examining, in the spirit of Diamond (1999) the impact of the different timing of the Neolithic revolution across the world on the development of statehood (Borcan et al., 2016; Ang, 2015) or those focusing on differences in transparency of agricultural output and the role of environmental circumscription in ancient states (Mayshar et al., 2017; Schönholzer, 2017). Fenske (2014) analyses the role of different gains from trade due to differences in ecological diversity for state capacity in pre-colonial Africa. Exceptions to this are Abramson (2017) and Ko et al. (2016). These papers analyze the determinants of political centralization and state formation for very early periods or over a very long time (e.g. from the Middle Ages until today) and, in this, are closely related to our paper in this.

(Weber, 1919). Others do not believe in a voluntary contract, but in states emerging from coercion by a 'stationary bandit' (Olson, 1993) stealing from his subjects.[5]

What both sides agree on is that this 'contract', either voluntary or involuntary, exchanges violence (protective or coercive) in return for taxation. Many authors have therefore stressed the role of the former and view military technology as decisive for state development (see Tilly, 1993; Diamond, 1999; North et al., 2009; Gennaioli and Voth, 2015; Boix, 2015; Ko et al., 2016). Museums and arsenals of historic tools, weaponry, and war records from most of human history have guided the understanding of the role of the horse, the chariot, the canon, or general conscription for political order. The other side of the contract, efficient taxation, is less prominent, but understanding it is decisive for modern development economists. At its core aspect is the quality of information about taxable output. The weaker the information, the more our bandit would find himself between Scylla and Charybdis. Demanding an excess of taxes, he bites the hand that feeds him. Demanding too little, less modest rivaling bandits will take his place. Free-riding and false accusation of free-riding also threatens also the consent of those governed by a voluntary contract. Both the voluntary and the involuntary contract suffer from the problem of asymmetric information between the source of the taxes and the provider of 'security'. From the perspective of a peasant who is overtaxed due to false information, the distinction between these two origins of a state is, therefore, of purely theoretical nature.

In addition, overtaxation will lead rational agents to hide some parts of the harvest (and spend effort trying to avoid being caught), just to prevent starvation. States can try to reduce information asymmetries by creating a political order, a hierarchy, to collect data on agricultural output. This introduces multiple principal-agent problems and the problem of rent-seeking (Krueger, 1974; Olson, 2008; Acemoglu and Robinson, 2012). Therefore, imperfect information about taxable agricultural output translates to high information costs, undermines political institutions, may lead to conflict within a state, reduces state capacity, and in the end limits the states development in general—and precisely because of the information asymmetry, this is true even with the most benevolent ruler. Unlike winners of wars, rent-seeking tax collectors, lords, and officials did not

[5]This view of an involuntary agreement is shared by figures as prominent as Marx and Engels, but also Tilly (1985). See Fukuyama (2011, Ch. 21) for an overview. An addition to this argument is the circumscription theory by Carneiro (1970). Carneiro noted that early states emerged predominantly in areas surrounded by infertile areas (such as deserts), and assumed this provided a natural barrier against fleeing from violent rulers.

boast about their successes. Their relics seldom survived in a form to anything that could be excavated today and analyzed in a structured fashion today. However, state capacity in an early agricultural society has to be viewed as an equilibrium solution between military technology *and* taxation.

To formalize this argument, we develop a macroeconomic model that links state capacity to geographic circumstances, namely a combination of the quality, and observability of agricultural output. This model is inspired by the study of Mayshar et al. (2017), who develop a principal–agent model of an agricultural state, in which state rulers maximize state revenue under information asymmetry about agricultural output, which is geographically determined. If output is perfectly predictable, rulers can extract full effort from their subjects. In a state with a high spatial variation of soil quality, for example, the actual quality of a single plot is hard to observe, meaning the ruler will have to estimate the endowment. The lower the observability of soil quality, the lower the state capacity. The more heterogeneous, and thus less observable the productive potential of each plot, the higher the costs of observation.[6]

Our theoretical model extends the work of Mayshar et al. (2017) several respects. Their model is not empirically testable as they only distinguish between two types of soils, those with low and those with high observability and provide only two case studies from ancient times. We generalize their micro-level principal-agent model to a macro-level two-sector output model with a continuous observability measure. We also extend their model to explain the failure and survival of feudal states and the changing importance of agricultural and economic determinants of state capacity over time. Urbanization is now modeled as part of rulers' optimization problem.

To test our theoretical propositions empirically, we compute a variable that proxies the observability of agricultural output (and thus the information costs in an agricultural society). This measure is based on spatial variation of the crop suitability within a region. Output is measured using the average caloric yield that can be obtained from harvesting crops. We base our measure of observability on the caloric suitability index developed by Galor and Özak (2014, 2015). This index denotes the amount of calories that can be produced in a given area, averaging over the individual

[6]Our reasoning is also based on the fact that medieval rulers, for example Charlemagne, were not only interested in increasing agricultural output, but also in increasing its observability, uniformity and comparability (Henning, 1994; Hermann, 1985)

caloric yields obtained from planting all suitable crops. This index covers the periods before and after the Columbian exchange. Based on this index we calculate our observability measure as a ruggedness index of caloric yields, i.e. we measure the variation in agricultural output as the variance between the caloric suitability of each cell and that of its neighboring fields. Thus, we capture to what extent the agricultural output of a grid cell diverges from perfect observability (all cells within a grid have the same caloric yield).

We link this observability measure to the states in the HRE at six points in time (1250, 1378, 1556, 1648 and 1789), which are all decisive moments in Central European history (see p. of the Appendix). This allows us to abstract from the role of military technology, as this is common across our sample and has been studied extensively. We obtain information and states and their size by digitizing historical maps of the HRE (without the Italian parts) by Wolff (1877). After digitizing these maps, we validated and, if necessary, corrected them using literature on the history of territorial states in the HRE, such as Köbler (1988) and Sante (1964). We also collected reasons for the failure of states.

Using this unbalanced, state-level panel data set, we first show a robust and both economically and statistically significant positive relationship between observability of agricultural output and taxation. We proxy the taxation by the tributes towards the Empire, the 'Reichsmatrikel'. We then investigate how differences in observability are related to the failure or survival of agricultural states. The results suggest that states with low observability are more likely to disappear because of bankruptcy or war and that observability is positively linked to the probability of state surviving in the Middle Ages. In the following, we find observability being positively related to state size when pooling over all states and periods. The relationship also holds when estimating separate cross sections for each of the six years and when considering the characteristics of neighboring states. It is also robust to controls for many alternative determinants of state capacity, such as access to trade routes and rivers; the availability of important natural resources such as iron, gold or salt; trade fairs; imperial cities; terrain features such as ruggedness and elevation, temperature, suitability for ploughing; the type of the state (i.e. kingdom, duchy, princedom, county, city etc.); the number of battles per state area; and the effect of differences in the appropriability of crops. Results pass various tests of robustness. We use the settled area of a state as dependent variable

(the area that is not forested or marshland or the like). We take levels of agricultural observability and state area instead of natural logarithms. We employ an alternative version of the agricultural observability index (based on the assumption that only the crop with the highest caloric yield is planted), and another version of the index. The cross-sectional estimates, and alternative OLS regressions in which the agricultural observability index is interacted with period dummies, are in line with our theoretical reasoning and historical evidence. Agricultural observability looses its significance as a determinant of state capacity in the early modern period, more specifically in the 16^{th} century. As outlined earlier, this is the timing we would expect. In this point in time, structural changes made the scale effect the dominant factors in predicting state capacity.

Below we provide an overview of relevant historical features, such as the political and societal structure of the HRE. We continue by developing the theoretical model that connects the principal-agent problem to state capacity and size. We introduce the data and outline our empirical strategy to test the theoretical model. This includes a discussion of alternative influences on pre-modern state capacity, and also how we address them. We will discuss the empirical results, and then conclude.

I. State Size in an Agricultural Society

We define a state as a geographical unit that competes with fellow states over both territory and labor supply to generate taxes. We are therefore interested in the tax capacity of such a state, and its influence on geographic size and survival. Our model state is predominantly agricultural, as this was by far the leading occupation throughout human history (see Allen, 2000, for estimates). We assume that land rents are Ricardian, and that a state's tax revenue is a function of the available land area and labor force. The general idea that the geographic size of a state is at equilibrium between increasing returns to scale in providing public goods and increasing obstacles to this provision [7] is well established (see Spolaore, 2014, for a recent overview). Consider Figure 1. Following Bean (1973), we view defense of the territory as the predominant public good, which is provided at decreasing costs per unit of land. During the High Middle Ages changes in technology

[7] Both Alesina and Spolaore (1997) and Bolton and Roland (1997) view heterogeneous preferences as the obstacle for modern states

amplified these decreasing returns to scale, in the 'Military Revolution' (Tilly, 1993; Gennaioli and Voth, 2015; Boix, 2015).

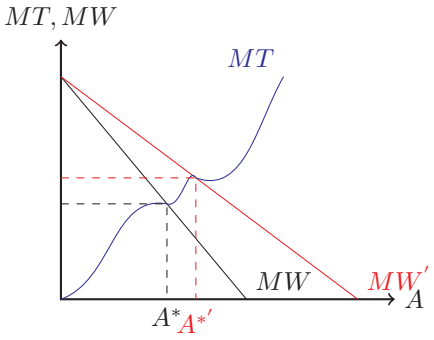


Figure 1: *Stylized equlibrium area (A^*) of a state in equilibrium between decreasing marginal costs of warfare, MW, and increasing, geographically induced and non-linear marginal cost of taxation MT, before and after the military revolution that shifts military costs to MW′ starting around 1500*

Already Adam Smith was concerned with obstacles to state size and capacity, and proposed a mix between geographic variables and administrative constraints

"In countries, such as Italy and Switzerland, in which, on account either of their distance from the principal seat of government, of the natural strength of the country itself, or of some other reason, the sovereign came to lose the whole of his authority. [...] This is the short history of the republic of Berne as well as of several other cities in Switzerland. If you except Venice, for of that city the history is somewhat different, it is the history of all the considerable Italian republics, of which so great a number arose and perished between the end of the twelfth and the beginning of the sixteenth century."[8]

Concerning distance, Olsson and Hansson (2011) have recently shown that across modern countries there is a robust negative relationship between country size and rule of law.[9] In theory, there can be three reasons for their finding. First, the complexity of the process upon which that information is collected (unrelated to distance). Second, the transfer of the information through the organizational structure of the state (weakly related to distance, depending on circumstances). Third, the loss of information due to the physical transport of the information, which we positively rule out for modern times given communication technology.

Regarding the first, more complex processes are harder to understand. Mayshar et al. (2017) show this with Egyptian agriculture, a fairly simple process. The Nile carried with it fertile soil and

[8] Wealth of Nations, book III, ch. 3. Quoted edition Smith (1991)

[9] They also provide an overview of the history of this thought including prominent figures like Plato, Aristotle, Rousseau, and Montesquieu.

distributed it evenly across its banks. This means that a primitive tool, the Nilometer[10] was a reasonable indicator for harvest outcomes, in the form of a univariate relationship. By contrast, agricultural output in Mesopotamia depends on multiple variables, as irrigation was more complex. The process of agriculture in Western and Central Europe was even more complex, and not well understood in the Middle Ages. There are some homogeneous landscapes, where properties of the soil are very uniform, the terrain is even, the wind blows all seeds in the same direction, etc., and other landscapes, where none of this is true. Taxation of output from these landscapes will naturally be based on estimates, and these can vary in their quality. Lacking an objective tool (like the Nilometer), these estimates relied on self-reporting (van Schaïk, 1993; Vogeler, 2005). We will outline how different levels of variation, which are geographically determined, yield different qualities of information, and induce information costs.

Information about agricultural output is necessary for taxing an agricultural society. Meteorology, the science of measuring and predicting weather and climate, was rediscovered during the Renaissance. Behringer (1999) goes as far as viewing the emergence of meterology to predict agricultural output as a counter-reaction to witch-hunting—the prevailing practice for overcoming harvest failures during 1300–1600. We can assume that the state of meteorology was so weak, and that investment into the understanding of factors that determine the harvest was so costly, that tax collection depended on adaptive expectations, and also local gentry and officials who were familiar with subjects and landscape. This explains hierarchies, such as the Chinese bureaucracy, the Mamluks in the Middle East, and also the feudal system in Western and Central Europe.[11]

Relying on local knowledge has downsides. In any such hierarchy there is loss of information, even if the incentives of all participants are aligned. In an analogy to the telephone game, there would be some loss of information, but driven more by the number of hierarchy levels than distance.[12] The levels of hierarchy in the HRE were however not dependent of its size, but mostly

[10] A Nilometer is essentially a set of marks to measure the water level (see Mayshar et al., 2017).

[11] It is important to note that the feudal system was not built from scratch, but relied on existing tribal hierarchies. The alternative, demonstrated by China, reveals however that these structures could be eroded, if the central power is strong enough. This in turn allows us to measure information costs half a millennium ago, unlike in other areas of the world. One can assume that asymmetric information in a bureaucracy would translate to e.g. corruption, which is hard to observe in a historical context. (see also Mitterauer, 2004; Fukuyama, 2011).

[12] Consider playing the telephone game. The quality of information is reduced slowly but continuously over time (as people forget) which would be analogous to the distance in our context. Much faster, and the core of the game, is the sharp drop in information quality between two players when one player has to listen and repeat the information.

due to tradition. This could lead us to reject incentive-aligned tax officials if we observe variation in state capacity despite the same number of levels in the hierarchy. At any level in the hierarchy there is a principal-agent problem, and these problems combined limited the expansion of the state.[13] In the next section, we will trace these problems through the hierarchy of the HRE and show how we can measure them in aggregate.

II. Taxation in the Medieval Holy Roman Empire

We follow the literature in regarding the medieval Roman Empire as a chain of bilateral contracts (North and Thomas, 1971; Volckart, 2002), through which security is provided from the top down in exchange for goods and services (see Bean, 1973; North et al., 2009; Olson, 1993). In Figure 2, we see the ends of the chain of bilateral contracts held by the Emperor and the households. Our element of interest, the territorial states, contracts directly with the Emperor, but only connects to households through intermediaries. We will outline how the rents that gentry and officials gain from inter-mediating between state and household are a loss to the rulers, and how rents arise endogenously from the multi-layer principal-agent problem.

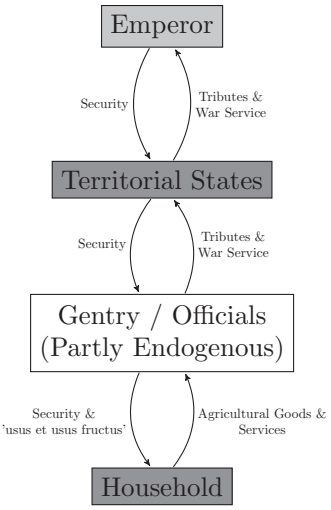
1. Households and the Gentry

The lower end, and the smallest political unit of the HRE was the household (see (Wilson, 2016, p. 508) and (Volckart, 2002, p. 33)). Volckart (2002) distinguishes between three types of contracts that exchange either services or agricultural goods between the household and the low gentry and officials. The most prominent of these was the feudal contract, in which a lord (lat. vilicus) provides security in exchange for agricultural output and compulsory labor for the feudal lord (corvee). The households had the right to decide the use of the land and the yields of the land ("usus et usus fructus" (Volckart, 2002, p. 40)), but would never gain property over it. This system, developed by the Carolingians, had its origins in the Late Roman Empire, when formerly free peasants were obliged to fill military granaries, and diffused eastwards into the Germanic areas

[13] The idea of non-aligned incentives in a company-like state, which is true both for a feudal society and a command economy, is taken from Harrison (2002).

(Mitterauer, 2004, p. 42ff.). The lord maintains certain rights of deposition over the feudal state, but grants the household (its serfs) the right to work on the land and retain a portion of the harvest to feed themselves.

Neither secular nor ecclesiastical states based their taxation upon tradition, but were flexible about the form and quantity of taxation. North and Thomas (1971) have argued that whether a lord would demand goods or services was a question of transaction costs, and depended on the lord's ability to market each of the products. We employ this idea in our model, since we identify all forms of taxation with their labor input. Inefficiency in acquiring information about the harvest posed a substantial risk to the lord. Tradition and written contracts certainly did not impose an upper bound for taxation, especially due to a very flexible and hence dynamic element: free provision of peasants' labor services. Labor services were not well codified (Volckart, 2002, p. 9), and allowed rulers to flexibly adjust the quantity of such services to circumstances. For example, a 1222 source from the Eiffel provides instructions on how to persuade peasants to take over new duties, selling them as old traditions (Epperlein, 2003, p. 76).[14]



Note: This graph shows how agricultural output and security are exchanged via a chain of bilateral contracts between the household on the one side and the emperor on the other side. The box 'Gentry and officials' represents multiple layers of bilateral contracts exchanging tributes & war services against the promise of security

Figure 2: *Model of the political structure of the Holy Roman Empire*

One of the most important threats to tax capacity was outmigration. Depending on the demographic circumstances, but especially following the Black Death, outmigration to another feudal state or a Free or Imperial city made states compete for peasants (Volckart, 1997, 2002), and one element of this competition was costs created by incomplete information.[15] Rulers' ability to

[14]Large and extensive corvees were not unusual (see e.g., the discussion in Blickle (2006) on the particularly repressive feudal system in the Baltic Sea area).

[15]The migration from rural areas to cities is considered among German historians to be an important aspect in the demise of the feudal system. They provide a several detailed accounts about conflicts between rulers and city states about fleeing serfs. One of the most conflicted topics between territorial states and cities states was the so-called urban dwellers ("Pfahlbürger"): people who lived outside the area of the city in villages but were citizens of the city—and hence not part of the feudal system. Emperors forbade this type of citizenship several times during the 14th century but did not succeed in preventing it (Blickle, 1988). However, as emphasized by (Ogilvie, 2007, 2011) urban labor markets in pre modern times

restrict this migration depended on features such as state capacity and the size of its territory—as it was easier to escape undetected from a small state than a large one (Blickle, 2006; Gerteis, 1997). Thus, some rulers were more successful in preventing emigration than others.[16]

Another threat arising from information asymmetries and information costs was revolt. Peasant revolts were common in the HRE throughout the Middle Ages and increased in frequency and intensity in the early 16th century, culminating in the German Peasants' War in 1525.[17] Although their overall success (especially in the Peasants' War) was limited, there are numerous examples of peasant revolts against (perceived) overtaxation, restriction of free movement and inheritance rules that resulted in a compromise between the ruler and the peasants. These gradually improved the situation of the peasants and weakened the feudal system in the long-term.[18]

Incomplete information about agricultural output also explains a common phenomenon during the Middle Ages, tax avoidance. The Sachsenspiegel (around 1230)[19], a rich historical source of medieval life in Saxony, allows us to understand how peasants attempted to cheat their rulers. It explicitly states that the quality of the tithe (an in kind payment to the local church officials of ten percent of the agricultural harvest of the season) has to be exactly the same as the share the peasant keeps (2nd book, Art. 48 §6). Rulers had to be informed about the estimated quantity of the harvest in advance, otherwise they could make their own estimate of their subjects' dues.

2. Gentry and Nobility

The intermediate level of the feudal societal order was the gentry, i.e. lower-ranked nobles like knights, officials ("Ministerialen") of the noble state ruler (like reeves) and also those counts and barons who ruled over a feudal estate that was not "reichsunmittelbar" (directly subordinate to the

were highly regulated by guilds, and they often successfully limited immigration to cities. Thus, migration to a city state might not have been possible for everyone or at all times.

[16] In the south west of the HRE, rulers found arrangements to deal with it, either by demanding several types of fees and compensation payments for permission to emigrate or by bilateral agreements with neighboring rulers that for each serf migrating to the territory of the neighbor they get one of the neighbor's serfs (Blickle, 2006). In the north, by contrast, they took measures to further punish migrants in order to restrict emigration, e.g. they made agreements with other rulers to send back strangers from other states who didn't have a an official dismissal allowance from their former ruler–but with apparently limited success (Blickle, 2006; Peters, 1995).

[17] The reader is referred to Blickle (2006) and Buszello et al. (1984) for detailed accounts of the Peasants' War.

[18] An overview of the history of German peasant revolts and uprisings in general, including several case studies is given by Blickle (1988, 2006) and Franz (1976).

[19] Cited after Epperlein (2003).

Emperor) but was given to them by a duke or prince. Those medium ranked nobles (the gentry) usually administered their territory under a higher-ranked noble. For example, counts originally served as vassals of dukes with responsibility for a particular county of the duchy. As such, they were responsible for the collection of dues and taxes in their feudal estate. These intermediaries could engage in rent-seeking (North and Thomas, 1971; North et al., 2009), keeping a certain amount for their own purposes and passing the rest to the overlord. They had to provide soldiers for the wars of the overlord in return for his protection. Hence, the principal-agent problem between them and the households discussed above, was relevant to the relationship between the overlords and the gentry. If the gentry could not appropriate enough taxes from the serfs (or overtaxed the households) the amount that the overlord received from the gentry was also reduced. Furthermore, as the local gentry had better information about the agricultural than the overlord, there is an additional principle-agent problem between gentry and nobility. The first has an incentive to cheat the nobility in order to retain a higher share of output for themselves. Of course, the incentive to conceal tax revenues increases as agricultural output, and the amount that is available for appropriation, decreases. This increases the severity of the principal-agent problem between the nobility and the gentry.

Territorial states saw these intermediaries as necessary to collect taxes, but also as a cost factor, aware that information asymmetries led to rent-seeking. As Bloch (1966, p. 134) wrote, the emergence of absolutism was "to protect rural communities, ripe material for taxation, from intemperate exploitation by their landlord".

3. Emperor and Nobility

At the top of the feudal order was the Emperor of the HRE, who was usually also the king of Germany. He was the supreme overlord and granted feudal estates to his vassals, the "Fürstliche Häuser" (princely houses). This originally meant dukes, princes, bishops and archbishops. They also had the right to 'subcontract' parts of their estates to lower-ranked nobles for administration (subinfeudation).[20] The Emperor also granted city rights (making cities directly subordinate

[20]The fact that the vassals had the right to give away parts of their estates to lower-ranked nobles also led to a decrease in the power of the Emperor over time. This was because, within the feudal hierarchy, a noble was subordinate only to his immediate overlord and not to those at higher ranks.

to the Emperor), and had the right to reallocate estates from disloyal or deceased vassals. In exchange for the feudal estate and troops for war and dues from the nobles (the 'Reichsmatrikel') he guaranteed security of their rights over the estate. The Emperor also had territories that he ruled directly. In those territories, the Emperor usually installed officials like reeves to collect taxes, administer the law and uphold order. Here again, the relationship between nobility and Emperor was characterized by a principal-agent problem, and again, the initial information problem between gentry and serfs determined the amount of dues, taxes and troops the Emperor could extract from the nobility. Most of the time the nobility had a better bargaining position than the Emperor as, especially during the Middle Ages, the Emperors did not directly control a large area. Furthermore, the German king was traditionally elected by the leading princes (the electors). Hence, he depended on the loyalty and favor of the most powerful territorial rulers. This allocation of power between the princes and the Emperor lead to a decline in his power during the medieval period and a decentralized, highly fragmented political landscape.[21]

III. Model

The purpose of the model is to connect information costs in a completely coercive society to tax capacity, as in Mayshar et al. (2017), and from there to connect the geographical size of rural states and migration to cities. We will employ a two-sector model of agriculture and proto-industry. To be consistent with the historical setting we will not allow for non-coercive institutions (see Acemoglu and Wolitzky, 2011; Boix, 2015), and only a negligible share of agricultural output is traded via markets (Ogilvie, 2001). We will outline a static analysis before turning to the system dynamics.

The optimization problem of our states is very complex, so that we constrain ourselves to the most simple notation, standard letters, omit explicit functional form, and explain our concepts mostly by comparative statics.[22] In general, states maximize tax revenue over an infinite time horizon. They

[21] The Golden Bull of 1356, the so-called constitution of the HRE, officially settled the election procedure of the king by the electoral college and confirmed the rights and privileges of the electors. This made those seven (and later up to nine) electors the most powerful rulers of the Empire.

[22] Consider any function $f(x)$ that is differentiable twice. We will use a shortcut to ease notation using $f(x\uparrow)$ if $\frac{\partial f}{\partial x} > 0$ and $f(x\downarrow)$ if $\frac{\partial f}{\partial x} < 0$.

aim to extract all of their subjects' output above subsistence.[23] They can do so by allowing their subjects to move to cities, adjusting their urbanization rate $u \in (0,1)$. States can also conquer other states' territories, which will affect their geographic size a, their average Ricardian land rent r, and the observability of their agricultural output N. Attacking other territories and defending against attacks come with adjustable costs V. States can also allocate parts of their budget to maintaining interior order G. These costs include tax administration, but also collecting information on tax cheaters, quelling uprisings, preventing subjects from fleeing the state or moving around the state against the state's interest, acquiring subjects from over states, and rudimentary poor relief. Decisions of state budgets and strategy are taken discretely for any year t. States have a common discount factor $\delta > 0$ so that the optimization is given by

$$\max_{u,a,r,N,V,G} \sum_{t=1}^{\infty} \left(\frac{T_t}{(1+\delta)^t} \right) \qquad \text{s.t. constraints}$$

which are described in more detail now.

1. General Model of the Economy

We will drop state and period subscripts for ease of notation, wherever possible. Consider any state that produces agricultural output R and output from proto-industry P, so that $Y = Y_P + Y_R$. The state is endowed with common labor L, which is split between rural L^R and urban L^P labor stock, depending on the urbanization rate u, $L_P = uL$ and $L_R = (1-u)L$. Agricultural output depends on common technology A_R, factor inputs L^R and soil S, which can be substituted at elasticity α, so that $Y_R = A_R L^{R\alpha} S^{(1-\alpha)}$. Output of the proto-industry depends on common technology A_P and manual work L^P at diminishing returns $\beta < 1$, so that $Y_P = A_P L^{P\beta}$. There is a common information technology $A_T \in (0,1)$ to collect taxes and assess agricultural output. States collect these taxes in the form of goods, or via direct labor services (North and Thomas, 1971; Volckart, 2002; Mitterauer, 2004). Subsistence in cities is higher than in the countryside as cities do not produce food and transport is costly, $s_P > s_R$. Therefore, tax income T is a function

[23] The idea that the taxes were so high that peasants were kept at subsistence can be found both in Smith (1776) and Malthus (1798), and is also a feature of Mayshar et al. (2017).

of $T^P(A_T \uparrow, Y_P \uparrow, s_P \downarrow)$. Subjects naturally prefer to live in cities (which we will show later). We can therefore solve for the urbanization rate that maximizes tariff revenue, which is found where the additional tax from a urban labor supply is offset by the loss from its higher costs of subsistence and the loss to the rural labor supply, $u(\frac{\partial Y_P}{\partial L^R} \uparrow, \frac{\partial Y_R}{\partial L^P} \downarrow, (s_P - s_R) \downarrow)$. States face costs $V > 0$ to protect their borders using common military technology A_V.[24] These costs increase with geographic size a, but have decreasing marginal costs per area (Bean, 1973). The investment in one period has consequences for the following periods. Castles need to be maintained, and unemployed soldiers would find employment as rowing bandits, so that $V_t(A_V \downarrow, a \uparrow, V_{t-1})$ with $\frac{\partial^2 V}{\partial^2 a} < 0$ and $\frac{\partial V_t}{\partial V_{(t-1)}} \geq 0$. This explains that there will be some states which will maximize tax revenue by minimizing the costs of defense, e.g. by building a wall around the city itself, setting $u = 1$ and not having any endowment of soil S. These are city states.

2. The Problem of Agricultural Taxation

States having $u < 1$ use soil as an input factor. Following Mayshar et al. (2017), states have incomplete information about soil quality and depend on estimates of agricultural output. Therefore, the state will organize tax collection in its territory by building a hierarchy. This hierarchy features distinct groups of households, which are groups of individuals. Rural households are only connected to the state only via a set of individuals, the intermediaries. Any rural household h is part of a set of households H that owes taxes to the tax official, or lord, g_1 at the lowest level of intermediaries l_1, which contracts the land from. In this way, various layers on other layers l_2,.. various intermediaries g_2,.. are interposed between the state and all its rural households H, $h \in H^{l_1}_{g_1} \subset H^{l_2}_{g_2} ... \subset H$. Using adaptive expectations about the quality of the soil, the lords or officials parcel this land and assign it to rural households. They can assess average Ricardian land rent r. However, the complexity of the interaction between weather and terrain affects fields in any period t in ways that are beyond their understanding[25], $S_{ht} = r_h + \omega_{ht}$ while $\lim_{t^* \to \infty} \sum_{t=0}^{t^*} \frac{\partial S_{ht}}{\partial \omega_{ht}} = 0$. Households naturally learn about their current soil endowment as they harvest. Anyone else

[24] This argument is in line with coercion, or violence as the source of states, as in Olson (1993). Tilly (1993), North et al. (2009), Gennaioli and Voth (2015) and Boix (2015) have based their arguments about the dynamics of state building on this aspect.

[25] Imagine two farms, one on the hill, and one in the valley, and strong rain for days. The hill farmer will find it sufficient to dig some temporary channels to help the excess water find its way downhill; the valley farmer will find his crops flooded.

has to rely on incomplete information about the soil quality[26]. Using adaptive expectations, the most local intermediary will allocate a plot of land to a household that maximizes tax revenue, depending on the average rent and the subsistence level, $a_h(r_h \downarrow, s_R \uparrow)$ as it cannot be optimal to keep the households below subsistence. This will not assure that households never starve, as the effects of the weather upon a specific plot are unobserved to anybody but the household, which is not trusted to share the information. Generalizing this point, due to the principal-agent problem on each layer, all layers from the lowest gentry l_1 up to state level n depend on own estimates. We assume that any level's signal about soil quality S^* is normally distributed around the actual endowment of rural household h with soil S in period t. The shape parameter N represents noise (a decrease in the quality) of the signal. From standard reasoning about information asymmetries back to Akerlof (1970) it follows that the signal gets weaker the further up the hierarchy, so that for any level k it is $\forall_{k=\{,1...,n\}} : S_{ht}^{*l_k} \sim \mathcal{N}\left(S_{ht}, N_h^{l_i}\right)$ while $\forall_{k=\{1,...,(n-1)\}} : N_h^{l_{(k+1)}} \geq N_h^{l_k}$. Any level k will however use this signal as the basis for taxation of household h and wish to leave all levels below it with subsistence only, $T_{ht}^{Rl_k}(Y_{ht}^{*l_k} \uparrow, s_R \downarrow)$.

What are the consequences of underestimating the soil endowment? Since $S_{ht}^* < S_{ht}$ it follows that some of the agricultural output cannot be taxed away. If the signal of the lowest level of intermediaries underestimates the soil endowment, this yields a potential rent y for the households, $y_{ht}^{l_1}(S_{ht}^{*l_1} - S_{ht})$ with $\frac{\partial y_{ht}^{l_1}}{\left(S_{ht}^{*l_1} - S_{ht}\right)} \geq 0$. This potential rent will be realized by rational agents depending on the probability of being caught cheating and the punishment (following the logic of Becker, 1968). Prosecution of households often ended with subjects being injured and dying, such that prosecution could reduce the supply of labor in the next period. If chances of being caught are high rural households will reduce their effort during the harvest, leading to a reduction in L. Lords also had the right to punish 'insubordination, persistent laziness,

[26]We can neglect Bayesian updating, mostly due to limitations on the tax collector's learning behavior. How do states learn about their subjects' soil quality in any period? A scientific model of the link between weather, landscape characteristics, and meteorology, was not available. States cannot learn from their subjects' words, but they can learn from what they observe, in the form of operant conditioning and social cognitive learning. If tax collectors observe an unexpected increase in some households' livestock, physical appearance, and living conditions in general, and increase the tax, this learning is part of natural human behavior, and therefore common technology. Learning from peers, e.g. if some intermediary finds out that another intermediary on the same level is richer than he is, the first intermediary might try to discover the reason. This might help to identify the households that cheat him based on shared characteristics with the households that his richer peer taxes more efficiently. He will do what his neighbor does, e.g. provide his tax collectors with better tools to assess, infiltrate his subjects with spies, etc. Soon, all intermediaries on this level will discover the trick, and the technology will become common. Tax collectors could try to learn by trial and error to retrieve a model on the effects of weather and taxation on what they can observe. As this is connected to starvation, out-migration, and uprising, these experiments would be very costly.

or deliberate neglect of their duties' (Whaley, 2012, p. 251), so that this labor reduction was also risky. In any layer, intermediaries therefore have the incentive to keep their agents from realizing rents, and hold on to them themselves. In the long run, it has different effects on the society who is the one extracting rents, but for the tax capacity of the state, it has only negative ones.[27]. The same principal-agent problem is repeated up to the level of the state n, which has the lowest quality of information $\left[I_{ht} \mid S_{ht}^{*l_n} < S_{ht}\right] = \left(y_{ht}^{l_1} + \sum_{k=1}^{(n-1)} y_{ht}^{l_k}(S_{ht}^{*l_{(k+1)}} - S_h^{*lt})\right)$. Knowing that on average any second period yields rents, long run rents in any state r relate to the information asymmetries of all rural households in $H = \{h, h_2, ...\}$ on all layers $l_1, ..l_2, .., n$, yielding $\lim_{t^* \to \infty} \sum_{t=0}^{t^*} I_{rt} \sim \{N_h^{l_1}, N_h^{l_2}, .., N_h^n, N_{h_2}^{l_1}, N_{h_2}^{l_2}, .., N_{h_2}^n, ...\}$. We can conclude that underestimation of harvests limits the tax capacity of a state by reducing taxes that could be gained from the potential output of household h in period t under perfect information Y_R by the rents $I\left[T_{ht} \mid S_{ht}^{*l_n} < S_{ht}\right] = T\Big(A_T, Y_{Rt}, s_t\Big) - I_{ht}$.

Now turn to the case of an overestimation of soil quality, which at any point in time t can leave any other element of the chain with agricultural output below subsistence after tax collection. In the end, this was mostly true for the households. First, assume that households did not want or could not leave the state—as we will focus on emigration later—so they decided to pay the taxes. One option would have been working on the side to get the taxes from other sources. This was dangerous, as it was highly illegal. Lords often sold households' extra labor supply to urban traders in form of monopsonies (Ogilvie, 2001). This included many forms of agricultural goods, and also intermediaries, such as yarn. To uphold Lords' income from these contracts with traders, the informal labor market was illegal. The illegal labor market can be characterized as an exchange of jobs undertaken by desperate households that often came with a health hazard plus a high risk of capital punishment in case of being caught. Second, households could also resort to violence, e.g. looting granaries. Third, households could starve. All three options had negative effects on households' ability to provide labor, which we will circumscribe with Q. Households could try to move to a city, or another state. Given that cities also allow their citizens to subsist, due to complete information on output, subjects living in a city cannot be overtaxed. If we imagine

[27] Arguing with Malthus, rents sought by households can lead to a higher population, until the returns to the factor of labor diminish, and emphasize the effect of bad harvests (see also Mayshar et al., 2017, 2015; Voigtländer and Voth, 2013). In case gentry and nobility realize the rents, this can undermine the political stability of the state, and also lead to a decrease in households' fertility due to rising prices for staple food following Engel's Law (Engel, 1857).

our medieval households to be disutility minimizing, they would naturally prefer to live in the town. However, as states use u as one of their decision variables to maximize taxes, they will only allow this up to the point at which it reduces overall tax revenues. This can render within state urbanization impossible.

Concerning migration to other states, we assume that all states are alike in their aim of extracting all of their subjects' taxable output, so that we can neglect tax competition between states. Consider migration from any state i to the rural area of another state j, which households perceive to be the most attractive due to its soil endowment and allows immigration due to its marginal product of labor $\frac{\partial Y_j}{\partial L_j}$. Migration of households to closer states is more probable than long-distance migration for two reasons. First, households need to collect information about the state they contemplate moving to (see Bursztyn and Cantoni, 2016). Second, their disappearance is less likely to be noted if it only takes some hours to reach the border (Volckart, 1997, 2002; Blickle, 2006). Therefore, fleeing time d, the probability and severity of the punishment when caught, and the perceived information asymmetries explain why migration from the household to the safe border of the destination state is central[28]. The net migration X from any territorial state i to any other territorial state j can be spelled out as $X^R_{ijt} = \sum_{h \in i \mapsto h_2 \in j} \left(N_h^{l_1} \uparrow, N_{h_2}^{l_1}, \left(\frac{\partial R_j}{\partial L_j} - \frac{\partial Y_i}{\partial L_i} \right) \uparrow, d_{hd} \downarrow, G_i, G_j \right)$ with $\frac{\partial X^R_{rit}}{\partial G_i} \lesseqgtr 0$ and $\frac{\partial X^R_{rjt}}{\partial G_j} \lesseqgtr 0$. Destination states could find it either beneficial to stop peasants from immigrating, depending on their marginal product of labor, by investing in G, but could also welcome the arriving migrants by investing in G and allocating them to a field to harvest for future seasons.[29] In the absence of labor market regulations, this would only depend on immigrants' marginal product and their subsistence needs. Following Domar (1970), emmigration also increases the ratio of land to labor and further increases states' reliance on their subjects. The most recorded form of outmigration was fleeing to cities, especially Imperial cities. As cities engage in proto-industry using technology A_P, and have perfect information about their citizens, migration to any city j depends on technologies, marginal product of labor in the city compared to rural areas[30], and observability $h \in i \mapsto h_2 \in j : X^P_{hjt} = \left(N_h^{l_1} \uparrow, \left(\frac{\partial P_j}{\partial L_j^P} - \frac{\partial P_i}{\partial L_i^P} \right) \uparrow, G_{it}, G_{jt} \right)$ while

[28] Carneiro (1970) and more recently Schönholzer (2017) go as far as viewing this mechanism as the nucleus of state formation. They claim that the impossibility of fleeing allowed coercive government.

[29] What we would today understand as poor relief was not established in German lands before the mid 17$^{\text{th}}$ century, nor was the problem of migrant poverty seen as a field of government action (Whaley, 2012, p. 261).

[30] Historic literature following Abel (1943, 1953) has focused on these factors, viewing the process of abandoning areas in

$\frac{\partial X^P_{rit}}{\partial G_{it}} \lesseqgtr 0$ and $\frac{\partial X^P_{rjt}}{\partial G_{jt}} \lesseqgtr 0$.

3. Government Under Information Asymmetry

We established that states have room to reduce, or avoid, negative effects of asymmetric information by spending on interior order G. This would deliver better information on tax cheaters, leading to a reduction in households shirking, but it could also just lead to more innovation in tax avoidance. States could also spy on subjects planning to flee the country, or deport unwanted immigrants. They could use police to suppress uprisings. It has also been recorded that agents were sent to collect anyone without a master from neighbouring territories (Whaley, 2012, p. 252), which is essentially another form of investing in G. 'Peuplierungspolitik' (populationist policies) (Whaley, 2012, p. 263), most prominently affecting religious minorities, were an outcome of this problem (see e.g., Hornung, 2014, for a later example). These costs G are the sum of the costs for all households, $G_{rt} = \sum_{h \in H} G_{rht}$. For any household h, spending is given by the characteristics of the household itself, but also all possible migration targets $h2, ...$, so that $G_{iht}\Big(A_V, A_R, A_C, N^{l_1}_{h_2}, ..., z_{hj}, ..., G_j, ..., N^{l_1}_h, N^{l_2}_h, .., N^n_h, N^{l_1}_{h_2}, N^{l_2}_{h_2}, .., N^n_{h_2}, ..., z_{hj_2}, ...\Big)$. Similar to V, investment in one period creates maintenance costs for future periods. Collecting information on emigration and tax avoidance builds on established networks of trustworthy spies, so that aggregate G is given by $G_t(\sum_{h \in H} G_{ht} \uparrow, G_{t-1})$ while $\frac{\partial G_t}{\partial G_{(t-1)}} \geq 0$.

The overall effect of overestimating the soil quality in period t can be given by the possible tax under perfect information less the negative impacts on the households that stay and the effects of emigration to all other countries J, so that $\left[T_{ht} \mid S^{*l_n}_{ht} > S_{ht}\right] = T\Big(A_{Tt}, R_t, s_t\Big) - \frac{\partial R_t}{\partial Q} - \sum_{j \in J} X^R_{jt}$. If these costs are ignored, they can undermine the state's existence. The two types of government spending we identified, V and G both have to be financed by taxes. If they cannot be financed, states are bankrupt, iff $T_t < V + G \Rightarrow \sum^{\infty}_{t^*=(t+1)} T^*_t = 0$.

This yields that

Proposition 1. *States with lower observability of agricultural output are left with a lower amount of taxes, ceteris paribus.*

Central Germany solely as an outcome of wage differentials induced by the Black Death.

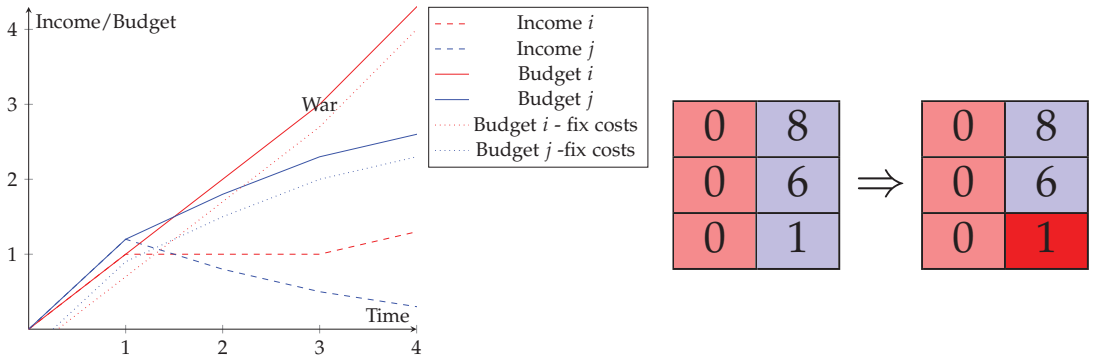
Due to the properties of the normally distributed signal we find that

Proposition 2. *States with a lower observability of agricultural output face a higher risk of bankruptcy.*

Now turn to the long run implications of this problem. Imagine the survival of a feudal state as a continuous struggle of the ruling family to raise an heir to marriage age, and to find an adequate match (Stone, 1961). In the tradition of Gale and Shapley (1962), this matching process requires a certain number of possible partners, and an ordered list of preferences for all partners. The German high nobility was relatively closed, which allowed marriage market participants to be well informed about what is on offer (Spieß (1993) and Hurwich (1998)). This gives us the proposition that other participants on the marriage market would notice their problems with efficiently taxing their subjects, moving them down their preference list on the marriage market, so that

Proposition 3. *States with lower observability of agricultural output are inferior on the marriage market*

4. War Over Territories With Information Costs



Note: At equal soil quality, state i's aggregated output from agriculture is perfectly observable, while state j's signal is distorted. Therefore i's aggregated income varies significantly between periods, which allows i to pay for the fixed costs of war and overcome j's defense to conquer territory from j after harvest in period 3. State i would do so conditional on the observability of the conquerable plots, and take over the best plots (indicated in dark red). After war, this would cause i to be larger compared to state i. Both states face a decrease in their average observability. Also, i faces a trade-off between the potential income, and the added variation of income between periods. If the conquest of one of the remaining plots would allow i to be attacked by another state (not in the picture), the visualized 'after war'-state is a new equilibrium.

Figure 3: *Stylized example of two states competing for territory. The plot on the left shows the income/budget of the states over time. The right visualization displays the observability of soil quality in two states, before and after i's attack on the southeastern plot.*

What explains war? Consider state budget, and keep in mind that V comes with increasing returns to scale. As outlined in fig. 3, under certain conditions, state i will find it profitable to conquer

territory from i. He would invest in V above the budget the defendant would have to invest in keeping the territory. If successful, the aggresor would increase its size a, which would also affect its average Ricardian land rent r. The aggressor would choose exactly the territory that yields the best combination of land rent, and observability, deduced by the one time costs of the attack and the recurring costs of defense. Depending on the magnitude of the increasing returns, a geographically larger state might maximize its long-run tax revenue by taking over territory that reduces its average land rent, and also its average observability. The higher the information costs of i, the less funds can be raised for defense. If increasing returns to scale become very large in magnitude, as implied by (Tilly, 1975; Gennaioli and Voth, 2015) for 16^{th} century onwards, this allows geographically larger and less observable states to overtake even more observable territories. In the long run, this yields

Proposition 4. *States with poor observability of agricultural output are geographically smaller, ceteris paribus.*

This shows that there are many channels via which information costs affect states, including the risk of rent seeking intermediaries, mass starvation, outmigration, civil unrest, urbanization, and war. We have linked this to geographical variables and the state of technology, which we assumed to be common across states. The central outcome of this model is that it is costly to states to solve problems caused by asymmetric information, and that in the long run this affects the survival of the state.

Proposition 5. *Any state with a higher observability of agricultural output than any other state also has a higher probability of survival*

Finally, it is well established that asymmetric technological and institutional changes in favor of proto-industrial technology, accompanied by a period of wars, flight to cities (Dincecco and Gaetano Onorato, 2016), and also the 'military revolution' led to an unprecedented urbanization after 1500 (Tilly, 1993; Voigtländer and Voth, 2013; Dittmar and Meisenzahl, 2017; Bosker et al., 2013; Boix, 2015). This hints at a reduction in the diminishing returns to labor in cities, $\beta \downarrow$, and also in the relative defense costs V for cities vs. territorial states. Territorial states would therefore increase u (reducing the role of soil, and reducing the need for hierarchy as population decreases), and city states would allow more immigration.

Proposition 6. *The predictive power of agricultural observability diminishes over time, especially after the structural changes around 1500.*

IV. Data

1. Dependent Variable: State Size

To calculate the size of a state, we digitized maps of the "reichsunmittelbare Territorien" (territories directly subordinate to the Emperor) of the HRE (without its Italian parts) as provided in the atlas by Wolff (1877).[31] These were the most detailed maps we could find. Furthermore, Wolff drew maps for the periods of decisive historical events of the HRE. These dates are 1250 (collapse of the Staufer dynasty) 1378 (peak of political fragmentation), 1477 (Peace of Nancy), 1556 (Peace of Augsburg), 1648 (Peace of Westphalia), and 1789 (outbreak of the French Revolution)[32].

The maps contain the names of the territories, and their borders. It includes all types of states in the Empire, i.e., city states (Imperial cities), large territorial states (kingdoms, duchies, principalities, margraviates, counties etc.) and ecclesiastical states (bishoprics, archbishoprics and monastic territories). However, each map contains white and unnamed territories (either because the name of the territory was not certain or because the territory or territories were too small to be included in the map). We tried to populate these white areas by comparing the different maps (as sometimes a territory is included in one map but not in another one) and we also overlaid the maps with Google maps. This enabled us to identify the territories based on the cities located within them. We were also able to considerably reduce the white areas in the maps but still, especially in 1477—when the map is less detailed than in the other years—some white areas containing very small states or that were divided between several states in a complex manner,

[31] To define only territories that were directly subordinate to the Emperor as states seems to be the consensus among German historians the reason is that only those states had a degree of independence somehow similar to modern sovereign state. States not directly subordinate to the Emperor were subordinate to a higher ranked ruler of another state (e.g. a duchy), and the rulers of those state received them as a feudal estate ("feud"). However, their power over the territory was limited. Another concern with the maps is whether the de jure situation was consistent with the de facto situation. There could for example be territories that were not directly subordinate to the Emperor but nevertheless were de facto independent. In Appendix A.1.4. we describe in detail who we decided when this was the case and also discuss some examples of states where this was an issue.

[32] A detailed historical overview of these critical points of Central European history is given in section A.1.3. of the Appendix.

remain. Nevertheless, as far as we are aware, ours are the most detailed and comprehensive digitized maps of the states of the HRE currently available.

To validate and cross-check the maps and the included territories, we compared them to several other maps of historical states in the HRE, including those of Darby and Fullard (1978); Stier et al. (1956); Andree (1886), or Baldamus et al. (1914). Furthermore, we consulted the "Historisches Lexikon der deutschen Länder" (Historical Encyclopedia of German States) (Köbler, 1988), a comprehensive and reliable source that provides a historical overview of each German state from the Middle Ages until the late 20th century, including their inception and downfall, the reasons they disappeared, their legal status and name changes. We also consulted the first volume of the "Geschichte der deutschen Länder" by Sante (1964), a monograph about the history of the German states during the medieval and early modern period, that also includes detailed histories of all territories. We used these publications to verfiy their existence and location. We further checked that they were correctly classified by type, e.g. as a duchy or county.[33]

Errors as to name, type of state or omission of an existing state occurred sometimes. Such problems mostly arose in the case of small states on which information is limited even today (typically some "Herrschaften", states ruled by a baron or an imperial knight), when there were several territories with the same name (e.g. "Limburg") or for a few of Imperial cities in the Alsac-Lorrain region which Wolff forgot.[34] However, we were able to resolve almost all of these issues, sometimes by consulting additional sources such as books by local historians.

Another difficulty was determining the start and end point of a states' independence. The latte was problematic, when, for example, a states was split up between the sons of a ruler and three family lines ruled over three different parts of the former territory. Here, Wolff not always correctly recorded the division of the state, which we resolved. Sometimes, after a ruling dynasty died out due to a lack of a male heir (or after a war about its heritage) a territory was partitioned between

[33]To validate the city states drawn in the maps we also consulted Cantoni (2012) and the "Deutsche Städtebuch" (Handbook of German cities) (Keyser and Stoob, 1939–1974) an encyclopaedia containing information on the history of each German city from its foundation/ first mentioning until the 20th century.

[34]Another case was that of the Imperial city of Friedberg and the burgraviate of Friedberg, located around a castle next to the city. The latter was a very small county around the castle of Friedberg that was involved in various conflicts with the nearby Imperial city. Wolff does not include both territories before the 1789 map, where he drew a territory called Friedberg and marked it as an Imperial city. We split this territory between the Imperial city and the burgraviate from 1250 to 1378. In 1477 the Imperial city lost its independence (it was under the control of the burgraviate then for most of the time) and thus, we assigned the whole territory to the burgraviate in the later maps—the burgraviate existed until 1806.

several other rulers. In this case, we decided whether to assign the territory to the state that had the majority of rights or whether it remained an independent state (when there was no clearly dominant party).[35][36]

Overall, we identified 730 independent states, including 81 city states, 89 ecclesiastical territories (bishoprics, archbishoprics and monastic states), and 560 secular territorial states. The latter group consists of two kingdoms, Bohemia and Prussia, 48 duchies, 80 principalities [37], 16 republics (all of them in today's Switzerland), 217 counties[38] and 180 "Herrschaften" (territories ruled by "Freiherren" (barons)). Furthermore, there were seven Imperial territories (directly controlled by the Emperor), among them were six "Landvogteien" (Grand Bailiffs) and one territory, the Staufian lands, controlled by the Staufian Emperors during the 11th to 13th century. There are also four territories that were occupied by the Swedes after the Thirty Years' War. Finally, there are nine electorates (among them three archbishoprics already counted above), which are considered to be the most powerful states of the HRE and are hence considered an own category.[39]

Figure A.2 provides an overview of the HRE and its territorial and city states in each of the six years for which we have a map from Wolff (1877).

[35]This was the case, for example, for the county of Sponheim which had a constantly changing political history. Details on this case and how we solved it can be found in Appendix A.1.2.

[36]A lack of clarity about when a territory ceased to be an independent state typically arose also because Wolff (and other historians) followed a tradition of drawing important states (like e.g., the duchy of Berg) as independent ("reichsunmittelbare") states even when they were de facto ruled by other nobles, as was the case for the united duchy of Kleve-Jülich-Berg which was split up again after armed hostilities over the different parts, with one part (the duchy of Kleve and the counties of Mark and Ravensberg) falling in the hands of the margrave of Brandenburg and another part (the duchies of Berg and Jülich) coming under the control of the duchy of Pfalz-Neuburg. In these cases we diverge from the map and make these territories part of Brandenburg or Pfalz-Neuburg, respectively.

[37]Apart from principalities, we also classify the following states into this category: Nine "Landgrafschaften" (landgraviates), 17 "Markgrafschaften" (margraviates) and two Princely counties (the Princely county of Burgundy and the Princely County of Tyrol). The reason for this is that the rulers of those states (the margrave, the landgrave etc.) were considered to have the same rank as princes (although their names refer to their origins as counties).

[38]The 217 counties subsume the following territories with "county" in the name: Four "Pfalzgrafschaften" (county palatinates). In general, the rulers of those territories (the palatinates) were considered to be of a higher rank than ordinary counts (in the case of a "Pfalzgraf" (Palatinate)). One of these county palatinates, the "Pfalzgrafschaft bei Rhein" (County Palatinate of the Rhine) had the status of an electorate from the middle of the 13th century (and was thereafter called "Kurfürstentum Pfalz" (Electorate of the Palatinate)). Thus, it still was called a county palatinate but actually was one of the most influential and powerful states within the Empire. Then, there are also six burgraviates and 207 ordinary "counties". It is important to note that counties were fairly heterogeneous regarding their size, and political importance. The county of Württemberg, for example, for a long time the largest county of the Empire (before it became a duchy in 1495), was larger than some of the principalities or duchies of the time and also had higher tax revenues than some of those higher-ranked territories. Hence, one should not assume counties to be less important or smaller than duchies or principalities.

[39]The official title of those states differed. Some of them were called "Kurfürstentümer" (electoral principalities) some are margraviates or county palatinates and the Habsburg monarchy called itself "Archduchy of Austria".

2. Main Explanatory Variable: Caloric Observability Index

To proxy observability, we propose an index that measures divergence from perfect observability as proposed in the theoretical framework. This measure of observability of agricultural output is based on the caloric suitability index developed in Galor and Özak (2014) and Galor and Özak (2015).[40] This index provides the average caloric yield per hectare per year for each grid cell on a resolution of 300 arc seconds (0.083 degrees or around 85 km^2).[41] The average is derived from the caloric suitability of all 49 crops for which the Global Agro-Ecological Zones (GAEZ) project of the Food and Agriculture Organization (FAO) provides global crop yield estimates and that can be grown in the area of a state (caloric yields¿0). Those estimated crop yields (given in annual tons per hectare) are converted into calories using information on the caloric content of the respective crops, available from the United States Department of Agriculture Nutrient Database for Standard Reference. The commonly used agricultural suitability measures of Ramankutty et al. (2002), or Zabel et al. (2014), report the fraction of each grid cell that is suitable for agriculture in terms of probability. Compared to those standard indexes, the caloric suitability index has several advantages. First, equally suitable land can have very different caloric yields, as land that is suitable for agriculture will not necessarily be suitable for the crops with the highest caloric yields. In a Malthusian subsistence society, the main purpose of agriculture is to feed the population, so the caloric yield is central. Second, the caloric suitability index accounts for the fact that prior to the Columbian Exchange not all of the 49 crops incorporated in the GAEZ database were actually available (e.g. potatoes were not available in Europe). Finally, the index is not endogenous to human activities, since Galor and Özak (2014) calculate the potential caloric yields assuming low level of inputs and rain-fed agriculture (it abstracts from irrigation methods) and agro-climatic constraints exogenous to human activities.

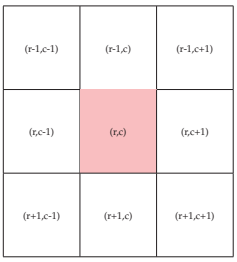
Our proxy for information cost, *CNoise*, is based upon the ruggedness index by Riley et al. (1999) that is applied to data on the caloric suitability index CSI[42] (not elevation). It is therefore defined

[40] The caloric suitability index can be downloaded here: `http://ozak.github.io/Caloric-Suitability-Index/`, accessed on April, 24th 2016.

[41] We use the version of the index that does not include crops with zero productivity in the respective grid cell for the calculation of the average caloric yields.

[42] This allows the usage of tools already implemented in QGIS or other GIS software and makes our results easy to reproduce.

for raster data, providing data for row-column-coordinates (r, c). *CNoise* of any state s is the average of all *CNoise* raster values in the state.[43] We construct *Caloric Observability Index* by linear transformation using the maximum over all states. This transformation has two semantic advantages. First, it is a positive index that translates to lower information costs, the higher the index. Second, it captures the idea that observability is a relative measure of comparable states that compete with each other; the state with the weakest observability serves as a benchmark.



$$CNoise(r,c) = \sqrt{\sum_{i=(r-1)}^{(r+1)} \sum_{j=(c-1)}^{(c+1)} \left[CSI_{(i,j)} - CSI_{(r,c)}\right]^2}$$

$$CNoise_s = \frac{1}{|(r,c) \in s|} \sum_{(r,c)\in s} CNoise_{(r,c)})$$

$$Caloric\ Observability\ Index_s = -1(\max_{t \in States} (CNoise_t) - CNoise_s)$$

For each column c and each row r, we derive the variance between the caloric suitability CSI and that of its neighboring fields. If this variance is zero, measuring caloric suitability of one field would perfectly predict the suitability of neighboring fields, and caloric observability is zero. With an increase in between-neighbor differences, the relationship between factor input and output becomes less observable, and the households' effort harder to observe. Hence, high values of the COI correspond to low observability and vice versa. To ease the interpretation of the COI, we transform it for the empirical analysis to ensure higher values correspond to higher observability.

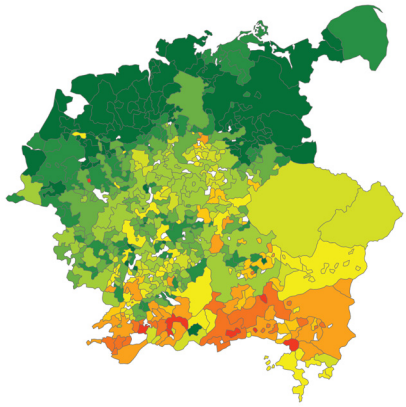
Figure 4 provides an overview of the average observability of the caloric yields of each state of the HRE in each of our six sampling years.

3. Other Explanatory Variables & Controls

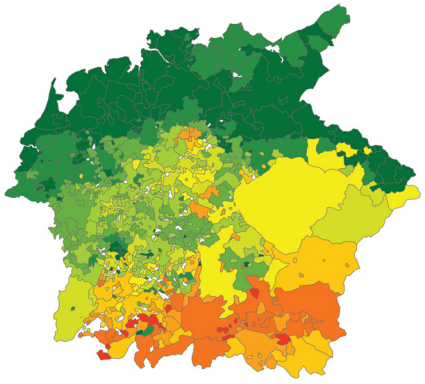
To limit concerns about omitted variables bias, we include a number of variables to our data set that should capture potentially relevant confounders of state capacity and size. Those are:

Agricultural conditions. A vast body of literature has pointed at soil quality as an indicator for

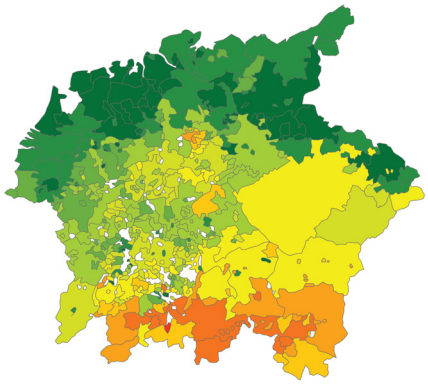
[43] This can be retrieved using the summary statistics tool in QGIS and ArcGIS, given the raster data and polygons on the states



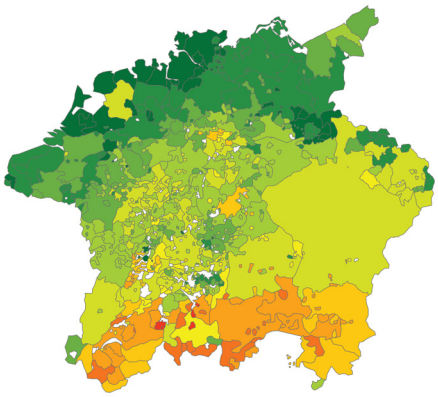
(a) *HRE 1250*



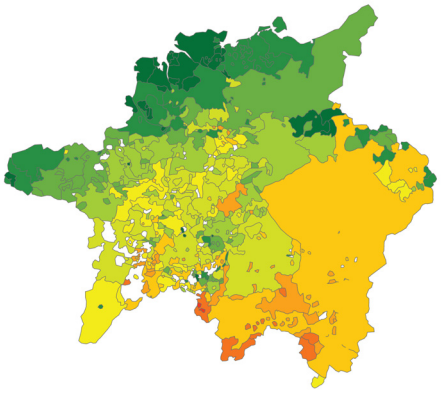
(b) *HRE 1378*



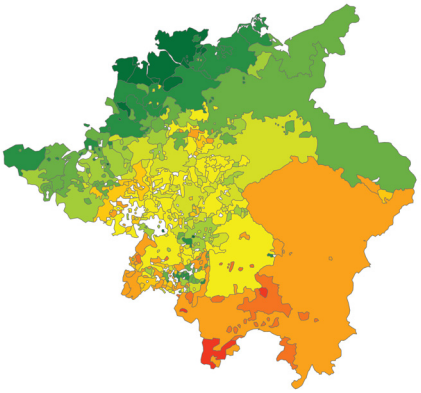
(c) *HRE 1477*



(d) *HRE 1556*



(e) *HRE 1648*



(f) *HRE 1789*

Note: These figures shows the average Caloric Observability Index in each of the territories of the HRE at the different sampling years. After 1500 New World crops become available due to the Columbian exchange and are included in the calculation of the COI. Increasing caloric observability corresponds to increasingly darker shades of green; increasing shades of red denote decreasing caloric suitability.

Figure 4: *Observability of Agricultural Output in the States of the HRE*

development (e.g., Diamond, 1999; Olsson and Hibbs, 2005). For example, von Thünen (1826) and more recently Lindert (1999) and Kopsidis and Wolf (2012) have pointed at the link between urban development and soil quality. Furthermore, the vast majority of the population was employed in agriculture and had to feed the growing urban population which produced all the innovations and proto-industrial activity. Thus, to account for the effect of the level of soil quality on state development, we use the caloric suitability index by Galor and Özak (2014, 2015) that we already have used to construct the observability index. A necessary prerequisite for crop farming was *deforestation*, which was mostly finished by the 12^{th} century (Wilson, 2016). We digitized data on areas still forested (or otherwse non-arable, for example, marsh land) during the Middle Ages, which is available for modern Germany from Schlüter (1952). With this variable we control for the share of a territory's area that was not deforested by the early Middle Ages. Finally, a growing body of literature is concerned with the *effects of specific crops*, such as the potato, on various economic outcomes (Nunn and Qian, 2011) and more recently Berger (2017). We therefore employ both the pre-1500 and post-1500 specification of the caloric suitability index. The fact that cereals, which can be stored and transported, are easier for rulers to appropriate could also be a factor (Mayshar et al., 2015). We control for this aspect with a variable measuring the productivity advantage of cereals over roots and tubers. Finally, we include the *average temperature* to account for climatic variations over time that could affect the agricultural output in each state.

Border States. Recently, economic research has found evidence that state capacity within historical and contemporary developing countries varies depending on the remoteness of a region (Olsson and Hansson, 2011; Michalopoulos and Papaioannou, 2014). Thus, in peripheral areas state capacity might be weaker. Looking at the HRE, it is evident that many of the border states were politically unstable and conflict-prone, and eventually gained independence from the Emperor (e.g. the Dutch Republic, Switzerland, the northern Italian cities etc.). Thus, we created a variable to identify countries that are located on the *outer border of the HRE* in each of our sampling years, to account for this. This also takes into account spatial effects of outward threats, especially the expansion of France and the Ottoman Empire (see (Iyigun, 2008)).

Disease environment. Acemoglu and Robinson (2001) and Acemoglu and Johnson (2007) proposed that diseases affect outcomes via political institutions. This makes diseases potentially

relevant for our study. We collected data on the location of medieval *swamp areas* as well as proximity to *rivers, trade routes, and Imperial cities*, which could have spread germs in the Middle Ages as outlined in Börner and Severgnini (2014) and Voigtländer and Voth (2013). (Diamond, 1999) has argued that everyday *contact between humans and livestock* creates resistance against diseases. This was predominant in all regions of Central Europe (Mitterauer, 2004), but shows some variation depending on the ruggedness of the terrain. We also include a variable measuring the average temperature of each state, as it is well known that germs favor higher temperatures.

Heavy Plough. Alesina et al. (2013) and Anderson et al. (2016) document a profound impact of the introduction of the heavy plough on gender inequality and city development. Thus, it is very likely that it could also have affected state capacity, e.g. due to significantly increasing the productivity of agriculture within a state that adopted the plough (or adopted it earlier). Higher productivity of agriculture increased agricultural output and therefore the absolute tax basis of a state. We account for the effect of the heavy plough by a variable measuring the fraction of a states' area that was endowed with *luvisol soils*, a type of soil that particularly benefited from ploughing.

Natural Resources. It is well established that the availability of natural resources such as gold, silver, salt and copper was a decisive factor determining a country's state capacity and tax revenues. Where minerals could have been exploited, mining was an alternative to agriculture, and rulers could generate high revenues from mining activities (historically particularly true for the Harz area and Saxony). To account for differences in natural resource endowments, we digitized maps of the geographic location of *copper, gold, lead, salt (rock salt and potassium salt) and silver*. Based on these maps we calculated a variable giving the average distance from 1,000 randomly generated points within a state to the next deposit of those resources. Additionally, we have data on areas within contemporary Germany that were still forested in the Middle Ages and hence provided a supply of wood—one of the most important raw materials in the pre-modern economy.

Outmigration. As discussed above, outmigration to Imperial cities posed a vital threat to the financial base of medieval and early-modern states. Thus, we compute a variable that proxies the outmigration opportunities by the average distance from 1000 randomly generated points within a state to the next Imperial city.

Pre-Existing Cultural and Historical Differences. We can account for the effect of a priori cultural differences in the HRE by assigning each of its later states to one of the states existing in 1150 using, again, a map of European states in 1150 AD by Wolff (1877). The states in 1150 largely reflected old, traditional borders of the territories of *Germanic tribes* (like the stem duchies, which reflected the territories of the Germanic tribes of the Bavarians, Franks, Swabians and Saxons).[44] To address the possibility of pre-existing, deeply rooted factors influencing state capacity in medieval Europe, we include a variable for the area of each state that was already settled in pre-historic times. These areas might have a longer history of statehood or other positive characteristics making them attractive for settlement.[45]

Terrain Characteristics. We also control for the *maximum elevation* above sea level and average ruggedness of a states' territory, using the digital elevation model provided by thee U.S. Geological Survey's Center for Earth Resources Observation and Science (EROS). Both factors could affect state capacity because they have an influence on the defensibility of the area of a state. Ruggedness could also have a direct influence on animal husbandry (see (Eder and Halla, 2017)) other than agglomeration (Kopsidis and Wolf, 2012). Taxation of animal husbandry could be different to taxation of crops.

Trade and Tariff Income. Trade affects our analysis in many different ways. First, trade was a source of revenue, as trading cities were usually wealthy and generated large tax revenues. Furthermore, trade took place along *trade routes, rivers and Roman roads* therefore rulers could impose tolls on trade routes and navigable rivers within their territories (Heckscher, 1955).[46] Tariff income from such road tolls could be significant and made some territories e.g., those straddling both sides of the Rhine, very wealthy.[47] Finally, if a lot of rivers or trade routes were located within a state, it was easier for its citizens (and the ruler) to access commercial centers. Therefore,

[44] After the Migration Period more than four centuries before, the areas in which different Germanic tribes settled have been relatively stable.

[45] We can also rule out nationalism as a unifying element within the HRE and a dividing element between different sub areas that would not be captured by tribal areas in 1150. There is wide consensus that nationalism cannot be attributed to Central Europe before the 18th century, if not the French Revolution (Weber, 1976; Anderson, 1983). We conclude from this that the sizes of states were too small for heterogeneous preferences in the spirit of Alesina and Spolaore (1997) or Bolton and Roland (1997) to limit the growth of states.

[46] There is a growing literature documenting the importance of the Roman road network for the long-run development of Europe (e.g.Wahl (2017)). This makes it even more important to account for the Roman road network and its possible effects.

[47] The small sizes of states introduce competition between them over trade routes, so that any single state can only raise its overall revenues from tariffs to the level that drives traders to change their routes (Huning and Wolf, 2016).

these states profited from better market access and lower transaction costs. We proxy for these advantages with variables measuring the average distance from 1000 randomly generated points within a state to the next Roman road, trade route or major navigable river. We also control for *trade fairs*, which were identified by Milgrom et al. (1990), and more recently Edwards and Ogilvie (2012) as classic example of medieval trade institutions. With respect to access to *financial markets*, the results of Volckart and Wolf (2006) suggest that there is a strong correlation between the spatial pattern of the integration of commodity markets on the one side, and financial markets on the other. We therefore assume to have controlled for spatial variation of financial integration with the above.

War and Conflicts. Several authors have argued that war and conflicts were a driver for state capacity in Europe, e.g. because of competition between states fostering technological and organizational innovations (e.g. in taxation technologies) (Hoffman, 2011; Karaman and Pamuk, 2013; Tilly, 1975). We construct a variable measuring the *number of battles* that had taken place within a state between 800 and 1378 AD, normalized by a state's area. Romer (2009) and Acemoglu et al. (2011) have pointed to the benefits of importing efficient political institutions, which in our historical setting is captured either via trade as a market for ideas, or conflicts. Radical modernization occurs well after the period in our study (also see Mokyr (2011)).

A descriptive overview of the variables in the data set can be found in Table A.1. Definitions and the sources of all the variables can be found in the Online Data Appendix (Appendix A.2). The maps on which we base our geographic variables are in section A.4 of the Appendix.

V. Empirical Analysis and Results

1. Caloric Observability and the Financial Capacity of States

We expect a significant and positive statistical relationship between caloric observability and the financial capacity of a state (proposition 1) and test this empirically. Following Cantoni (2012) we proxy the financial capacity and economic and military power of a state by its contribution (in

guilder) to the Imperial war tax ("Reichsmatrikel") in 1521.[48] The Reichsmatrikel contributions are taken from Zeumer (1913). We have matched the territories mentioned in the Reichsmatrikel with the states in our data set.[49] If a state existed in 1521 and 1556, we assigned its Reichsmatrikel contribution to the year 1556 in our data set. If a state existed in 1521 but not in 1556, we assigned its contribution to the year 1477 in our data set. Overall, we could match 236 states.[50]

We then run a cross-sectional regression where each state's Reichsmatrikel contribution is explained by its caloric observability and different sets of control variables. Thus, we estimate the following equation using the Poisson method, as the Reichsmatrikel contributions are left-skewed:

$$IMPERIAL\_TAX_{ic} = \alpha + \beta(COI_i) + \gamma' \mathbf{X_i} + \lambda_c + \epsilon_i \quad (1)$$

Where $IMPERIAL\_TAX_{ic}$ is the contribution of state i of type c in the Reichsmatrikel of 1521. COI_i is the caloric observability of a states' agricultural output. X_{ic} is a vector of different set of controls comprising of the variables introduced above. The set of basic geographic controls is made up of: of the following variables: average distance to a major river, maximum elevation, average terrain ruggedness and a dummy for states located on the outer border of the HRE in that year. Variables controlling for soils and climate are caloric suitability, average temperature, share of luvisol soils, and the productivity advantage of growing cereals instead of roots and tubers. The set of "Economic Factors and Resources" variables includes the average distance to the closest trade route, trade fair, Roman road, Imperial city, copper, gold, iron, lead, potassium salt, rock salt or silver deposit. λ_c are state type dummies (for Kingdoms, Electoral States, ecclesiastical territories, Duchies, Princedoms, Margraviates, Counties, Republics and "Herrschaften"), capturing unobserved shocks that might have affected different types of states in a different way and also unobserved historical factors making a certain state a kingdom and another one only a county.[51]

[48] There are three types of contributions: states had to contribute mounted and foot soldiers as well as a certain contribution in guilders. To monetize the whole contribution we follow Cantoni (2012) and assume—in line with the historical literature—that the pay of a mounted soldier was 12 guilders and that for foot soldiers was 4 guilders and multiply for the number of each type of soldier.

[49] It is known that the Reichsmatrikel list has errors, i.e. it contains states that were not or no longer independent ("reichsunmittelbar") or for which this status is doubtful. Furthermore, our maps give us information about the states in 1477 and 1556 but not for 1521. Thus, we have to rely on information from Köbler (1988) and other sources to match the states in our maps to those of the Reichsmatrikel.

[50] The average Reichsmatrikel contribution was 629.4 guilders with the minimum being zero and the largest contribution being 11,940 guilders (from the states controlled by the Habsburgs).

[51] The base category remaining are states occupied by the Swedish after the Thirty Year's War and Imperial territories directly controlled by the Emperor (i.e., bailiffs and Staufian territories). The electoral states are not double counted as they are not coded as e.g., Duchy, Margraviate, Kingdom, or County Palatinate.

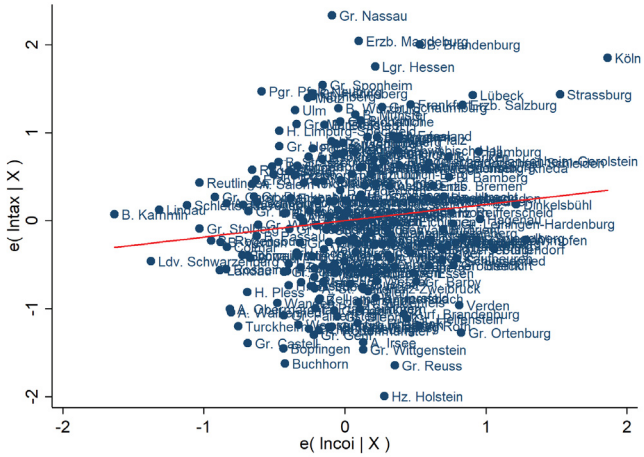
ϵ_{ic} is the error term.

Results are shown in Table 1. They show that, reassuringly, there is statistically and economically significant positive relationship between the Reichsmatrikel contributions and caloric observability. This relationship—while being statistically significant— is almost unaffected by the inclusion of different sets of control variable. This positive relationship does not depend on the Poisson method. Figure 5, shows a partial regression plot, but instead of Poisson using OLS to explain the natural logarithm of the contributions, as in by Cantoni (2012). The main explanatory variable is the natural logarithm of caloric observability, all other controls as in column (4) of Table 1.

Table 1: *Caloric Observability and Financial Capacity of States*

Dependent Variable	Reichsmatrikel Contribution			
	(1)	(2)	(3)	(4)
Caloric Observability	0.243**	0.247**	0.291**	0.289**
	(0.115)	(0.120)	(0.114)	(0.115)
State Type Dummies	✓	✓	✓	✓
Caloric Suitability	✓	✓	✓	✓
Basic Geographic Variables	✓	✓	✓	✓
Caloric Suitability	✓	✓	✓	✓
Soils and Climate	–	✓	✓	✓
Economic Factors and Resources	–	–	✓	✓
Battles per Area	–	–	–	✓
Observations	236	236	236	236
Pseudo R^2	0.607	0.615	0.651	0.653

Notes. Heteroskedasdicity robust standard errors are reported in parentheses. Coefficient is statistically different from zero at the *10 % level. The unit of observation is a state. All regressions include a constant not reported. State Dummies are dummy variables indicating electoral states ("Kurfürstentümer"), kingdoms, margraviates, duchy, princedoms, counties, republics, "Herrschaften" and ecclesiastical states. The set of basic geographic controls comprises a variable measuring the average distance of 1,000 randomly distributed points within a state to the closest major river, its maximum elevation above sea-level, its average ruggedness and a dummy for states adjacent to the boundary of the HRE. Soil and climate controls include the natural logarithm of a state's average caloric suitability index, the average caloric suitability for growing cereals relative to grow roots and tubers, the fraction of a state's area with luvisol soil that benefits most from plowing and a measure for the average temperature in a state. The control variables in "Economic Factors and Resources" include variables measuring the average distance of 1,000 randomly distributed points within a state to the closest Roman road, major medieval trade route, trade fair, gold, copper, silver, iron, lead, potassium salt or rock salt deposit.



Note: This figure shows a partial regression plot of ln(Caloric Observability) for the regression in Table1, column (4)

Figure 5: *The Relationship between Caloric Observability and Financial Capacity of States*

2. Caloric Observability and the Failure and Survival of States

To investigate our theoretical propositions 2, 3, and 5, regarding the relationship of observability and the fate of states, i.e. whether and how a state disappeared, we were able to collect data on 367 events leading to the failure (dissolution/ disappearance) of states, mostly from Köbler (1988) and other sources on regional history.[52] We grouped these reasons for failure into seven categories (see Figure. 6. In case a ruler died without a legal male heir, and the territory was either inherited by other parts of the family, partitioned within the family, or inherited by female heir and became part of her husband's territory, we classified state failure as *in family*. If the state was bought by, gifted to, or voluntarily joined another territory after the last ruler's death, it was grouped into *ex family*. As *bankruptcy* we classified all state failures in which the state was pawned and the state ruler failed to pay back the debt, so that the state changed owners while a legal ruler was still alive. We also classified all events of *Federal Rule* (the Emperor takes away the right to the feudal estate), and joining the *Swiss* Union. The category *War* we used when the territory was conquered by one ore more foreign rulers. To provide descriptive statistics of the link between observability and state failure, we provide box plots separated box plots of the COI for different categories of

[52]The territories that are lost in each of the maps as well as the reason for their disappearance are shown in Appendix Figure A.3.

reasons for failure. They are shown in Figure 6.

In general, the most frequent—and probably most unsystematic—reason for state failure was the death of a ruler without a male heir. This is not surprising, given that fertility of the nobility was generally low.[53] The probability of anybody dying of an accident or a common infection was high.[54] Adam Smith was right that the geography of Switzerland set it on a different path. Consider Figure 6a on the period before 1500 (reasons of state failure in 1250, 1378 and 1477). Most prominently, bankruptcy is the leading reason for failure of states with bad observability, which is in line with proposition 2 from the model. When the ruling family of a state ended without a single male heir, partition or inheritance by other states/noble families could be the consequence, which also includes inheritance by the first daughter's husband (in the plot: in family). States that were sold or given away, leading to the departure of the ruling dynasty (plot: ex family), were associated with about the same observability, with a few outliers displaying low observability. States that were conquered in wars were on average endowed with lower observability, which points towards the role of the decreasing marginal cost of protection on the victorious side.

Federal rule leading to the end of a state was rare, and so was secularization before the Reformation. After 1500 (Figure 6b), sorting by observability becomes more prominent, distinguishing within and out-of-the-family inheritance. Furthermore, bankruptcy is even more prominently associated with bad observability. However, those states that were conquered show a high observability pointing towards the direction of a regime change, which is a puzzle we will investigate further.

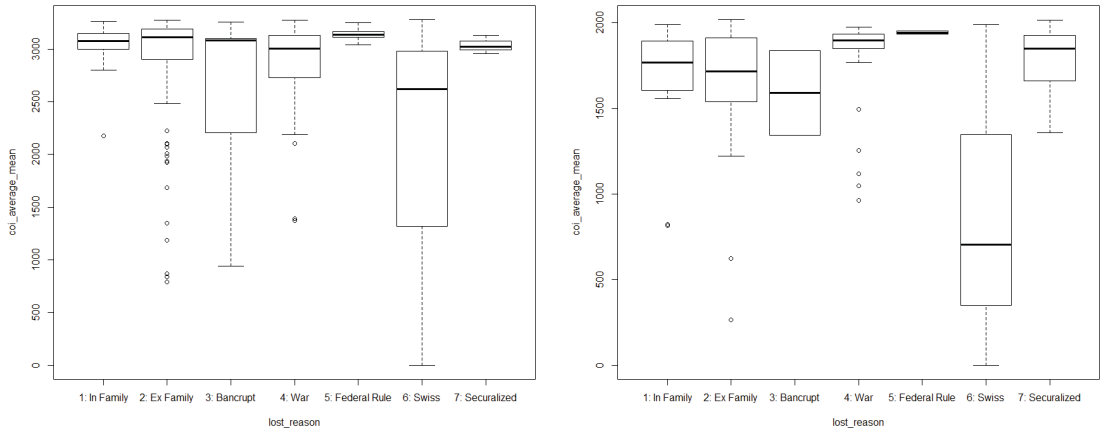
Is observability of agricultural output significantly positively associated with the survival of states during the Middle Ages? States with a high observability of agricultural output should be capable of remaining independent for a longer time due to better defensive capacities, more effective abilities to restrict outmigration, etc. To test this empirically, we run Cox proportional hazard models including all the baseline control variables (but, of course, no year dummies).[55] The results

[53] See e.g., Schröter (2007) for an overview.

[54] Cummins (2017) shows that during the Middle Ages, nobles regularly died on the battle field and their life expectancy was about 50 years.

[55] We estimate the Cox proportional hazard model using the Breslow method for ties. Other methods to handle tied failures like those proposed by Efron would yield very similar results. Those estimations are not reported but available uponn request. The results would also hold if we exclude the states who exit the data set because they left the Empire and became part of another state entity (like Switzerland) and because their ruling family extinguished (what arguably should be a random event in most cases). Results are available upon request.

are in Table 2 and suggest that, indeed, caloric observability was significantly positively related to state survival during the Middle Ages, but in the 17th and 18th century. To be precise, during the medieval period a ten percent increase in caloric observability raised the probability of a state surviving by around 0.6 percent.



(a) *Before 1500 (N=257)* **(b)** *After 1500 (N=110)*

Note: This figure distinguishes different reasons for failure of a medieval state. From left to right these are that a single heir was not present, and another branch of the family took over via marriage, partition, or inheritance rules (in family). If this was not the case, the territory was sold, given away, or left the dynasty (ex family). Bankruptcy was a reason for a living dynasty to loose their territory, war was another. Federal ruling leading to the loss of a territory was rare. The states to form the Swiss Confederation left the Empire. Some territories were secularized, mostly after 1556.

Figure 6: *Descriptive statistics of observability by different reasons states failed*

Table 2: *Observability and the Survival of States*

Dependent Variable	Periods a State Exist		
	(1)	(2)	(3)
	All Periods	Until 1477	After 1477
ln(Caloric Observability)	1.424***	0.94**	1.026
	(0.0563)	(0.0237)	(0.0371)
Baseline Controls	✓	✓	✓
Observations	1,925	1,083	842
Wald Chi^2	961.82	1183.61	2523.85

Notes. Standard errors clustered on state-level are reported in parentheses. The tables reports hazard ratios obtained from running a Cox proportional hazard model using Breslow method for ties. Hazard ratio is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state.

3. Caloric Observability, the Size of a States and the Dynamics of Statehood

We now test our theoretical proposition about the relationship between state size (proposition 4) and observability and the temporal evolution of this relationship (proposition 6). We run pooled OLS regressions using the unbalanced panel data set of states in the HRE as explained above. Our data set includes information on 730 states and for six points in time amounting to 1,925 state-year pairs being our observations. As observability of agricultural output is orthogonal to economic activities, political institutions and human activity—at least in the period studied—reverse causality should not be a critical issue. Nonetheless, there still could be a third (and unobserved) factor positively correlated with both caloric observability and political fragmentation. We address this potential bias by including several control variables, which were introduced in the previous section, in the regression specification. In addition to the control variables, we include year fixed effects to account for temporal shocks that affect all of the HRE equally, and we also include eight state type dummies. Thus, to identify our effect we only exploit variation in observability and state size within the same year and within the same types of states. To be precise, we estimate variants of the following regression equation:

$$ln(STATEAREA)_{ic,t} = \alpha + \beta ln(COI_{i,t}) + \gamma' \mathbf{X_{i,t}} + \delta_t + \lambda_c + \epsilon_{i,t} \tag{2}$$

Where $ln(STATEAREA)_{ic,t}$ is the natural logarithm of the area in km^2 of state i of type c in year t. δ_t are year dummies. The rest of the equation is defined as in equation 1 In robustness checks, we include dummy variables for the states to which a certain territory belonged in 1150 AD, dummy variables assigning each historical state to its modern-day equivalent, and variables reporting certain characteristics (e.g., area, soil quality or observability of agricultural output) of neighboring states.[56]

Later in the empirical analysis, we want to identify the temporal evolution of the effect of observability of agricultural output on state size. We estimate equation 2 as cross-sectional equation, separately for each year. Furthermore, we interact the caloric observability with the year

[56] We assigned a state to those state in 1150 or contemporary country in which the majority of its area is located.

dummies and estimate equation 3:

$$ln(STATEAREA)_{ic,t} = \alpha + \sum_{t \in \Gamma} \beta_t' ln(COI_{i,t}) \cdot \delta_t + \gamma' \mathbf{X_{i,t}} + \delta_t + \lambda_c + \epsilon_{i,t} \quad (3)$$

Where $ln(COI_{i,t}) \cdot \delta_t$ is the interaction of the COI with year dummies, and all other variables match those in equation 2.

First, we estimate equation 2 to statistically test the relationship between observability of agricultural output and state size. Results of the estimations are reported in Table 3. We start with a simple baseline specification only including year fixed effects and basic geographic control variables.

Caloric observability is highly statistically and economically significant with a one percent increase in observability increasing state size by around 0.5 percent. From columns (2) to (6) we add progressively more sets of control variables, to look how the coefficient reacts to the inclusion of covariates. In column (2) we add soil and climate controls, and the coefficient only decreases slightly. In column (3) we add variables proxying economic factors and resources. These variables decrease the coefficient of observability, but it remains economically and statistically significant. The inclusion of battles per state area in column (4) has virtually no effect on the results and the battles themselves are not significant. In column (5), nine state type dummies are added to further reduce unobserved heterogeneity.

However, this again leaves the coefficient of caloric observability almost unchanged.[57] In columns (7) and (8), we lose some observations, as we restrict the sampling area to the extent of the HRE in 1150. We do this, by including dummy variables that assign the territories of the HRE to the state to which they belonged in 1150 AD. As explained in the previous section, this is to account for pre-existing cultural differences, as the states in 1150 largely reflected the traditional territories

[57] With regard to the control variables, several interesting results emerge from this specification. For example, distance to the closest Imperial city is significantly positively associated with state size, pointing to the fact that outmigration may indeed have played an important role for the tax capacity of feudal states. Another interesting result is the significant positive effect of battles per state area and the negative and significant coefficient of distance to copper, iron, lead and potassium salt deposits. These indicate the importance of natural resources and war for the capacity of states. The significantly positive effect of maximum elevation also points towards defensibility of the area as an important factor. Finally, caloric suitability itself is positively related to state size, although the estimated coefficient (0.091) is much smaller than that of observability. Thus, it is not only the observability of agricultural output, but also the productivity of agriculture that matters, but observability seems to be much more important.

of Germanic tribes. The coefficient of caloric suitability further decreases but remains significant suggesting that a one percent increase in observability raises state size by around 0.13 percent. Finally, in column (7), the sample is restricted further to historical states within the borders of contemporary Germany, as we control for the area (in m^2) within a state that was already settled in pre-historic times (and hence, might have a longer history of statehood) that was still forested or consisted of swamps and flood plains in the Middle Ages. None of these variables stop caloric observability from being significant, although both forest areas and early settled areas show a significant positive effect. The coefficient remains about 0.25, and hence, increases again, when compared to column (6).

Table 3: *Observability of Agricultural Output and State Size*

Dependent Variable	ln(Area)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(Caloric Observability)	0.529***	0.500***	0.286***	0.287***	0.259***	0.141**	0.27***
	(0.0740)	(0.0727)	(0.0665)	(0.0665)	(0.0532)	(0.0527)	(0.068)
Year Dummies	✓	✓	✓	✓	✓	✓	✓
State Type Dummies	–	–	–	–	✓	✓	✓
1150 State Dummy	–	–	–	–	–	✓	–
Basic Geographic Variables	✓	✓	✓	✓	✓	✓	✓
Soils and Climate	–	✓	✓	✓	✓	✓	✓
Economic Factors and Resources	–	–	✓	✓	✓	✓	✓
Battles per Area	–	–	–	✓	✓	✓	✓
Early Settled, Forest & Swamp Area	–	–	–	–	–	–	✓
Observations	1,925	1,925	1,925	1,925	1,925	1,866	990
R^2	0.329	0.386	0.522	0.522	0.682	0.709	0.67

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. State Dummies are dummy variable indicating electoral states ("Kurfürstentümer"), kingdoms, margraviates, duchy, princedoms, counties, republics, "Herrschaften" and ecclesiastical states. The set of basic geographic controls comprises of a variable measuring the average distance of 1,000 randomly distributed points within a state to the closest major river and city state, its maximum elevation above sea-level, its average ruggedness and a dummy for states adjacent to the boundary of the HRE. Soil and Climate controls include the natural logarithm of a state's average caloric suitability index, the average caloric suitability to grow cereals relative to grow roots and tubers, the fraction of a states area with luvisol soil that benefits most from plowing and a measure for the average temperature in a state.The control variables in "Economic Factors and Resources" include variables measuring the average distance of 1,000 randomly distributed points within a state to the closest Roman road, major medieval trade route, trade fair, gold, copper, silver, iron, lead, potassium salt or rock salt deposit.

We then conduct checks to ensure that our baseline results are sufficiently robust. The results are in Table 4. First, we investigate the effect of modern country dummies on the preferred baseline specification (Table 3, column (5)).[58] The estimated coefficient, including those contemporary

[58]The HRE spanned 13 contemporary countries. These are Austria, Belgium, Switzerland, Czech Republic, Germany,

countries is reported in Table 4, column (1) and shows that the coefficient of observability only decreases slightly when these dummies are included. This suggests that unobserved heterogeneity connected to larger political entities (some of which were created during the existence of HRE e.g., Switzerland) does not decisively influence the effect of caloric observability.

Second, in column (2), we account for the fact that not all land in a state was either settled or suitable for agriculture, so considering the whole area of a state might introduce bias. Thus, we subtract from the overall area of each state those areas with forests, swamps, flood plains, lakes, estuaries and coastal marsh, to use this variable "Settled area" as dependent variable. As information on these areas is only available for contemporary Germany, the sample is again reduced to historical states within modern Germany. Again, the coefficient becomes smaller in magnitude but remains significant.

Third, in column (3) we show what happens if we take into account that, due to the different size of the states, some variables, like ruggedness, or caloric observability, that are calculated based on differences between the data points of the underlying raster data, could be mechanically higher in larger states. Thus, we inversely weight each observation by the number of ruggedness data points that are located within the state. Results are virtually identical.

Fourth, in column (4) we include a variable measuring the number of separated territories that make up a state. The medieval HRE was made up of non-contiguous areas. States with highly fragmented territory will have higher tax collection costs, information and defense costs might be larger, and it could be less susceptible to take over. However, this does not change the coefficient estimate significantly. The next three columns (5-7) show what happens if one estimates the preferred baseline specification using different variants of the caloric observability and state size measure. In column (5), we employ caloric observability and state area in levels instead of natural logarithms. The resulting coefficient is statistically and economically significant. Therefore, the results are not driven by taking the natural logarithms of both variables.

In column (6) we estimate the baseline regression using a caloric observability index also taking into account plants that become available only after the Columbian Exchange.

France, Hungary, Italy, Lithuania, Lichtenstein, the Netherlands, Poland and Slovenia. In the regression we include 12 modern country dummies, with Austria being the omitted country.

Table 4: *Observability of Agricultural Output and State Size—Robustness*

Dependent Variable	ln(Area)	ln(Settled Area)	ln(Area)		Area			ln(Area)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Robustness Check			Inversely Weighted by Ruggedness Count					Difference between post-1500 and pre-1500 COI for years¡1556
ln(Caloric Observability)	0.2307***	0.1974**	0.2711***	0.2253***				
	(0.0522)	(0.0863)	(0.0879)	(0.0511)				
Caloric Observability					1481615**			
					(699871.9)			
ln(Caloric Observability Post-1500)						0.296***		
						(0.06)		
ln(Optimal Caloric Observability)							0.3126***	
							(0.065)	
COI Post-1500-COI Pre-1500								0.0004
								(0.0002)
Baseline Controls	✓	✓	✓	✓	✓	✓	✓	✓
Modern Country Dummies	✓	–	–	–	–	–	–	–
Number of Territories	–	–	–	✓	–	–	–	–
Observations	1,925	827	1,925	1,925	1,925	1,925	1,925	1,450
R^2	0.692	0.591	0.857	0.703	0.4782	0.683	0.693	0.664

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. Baseline controls include year and state type dummies, the basic geographic, soil and climate, economic factors and resources controls as well as battles per area.

In column (7) we use a version of the caloric observability index computed under the assumption that only the crop giving the highest caloric yield is actually planted. This is winter barley in all states. Both times, the estimated coefficient is similar to that obtained in Table 3, column (5).

Finally, in column (8) we conduct a placebo-test. We only consider the years prior to 1556 (that is 1250, 1378 and 1477) and test if the difference in caloric observability before and after the Columbian exchange has explanatory power—which should not be the case. Reassuringly, these differences do not explain state size prior to 1500, making it unlikely that our results emerged by chance.

Another concern with the baseline estimates could be that not only characteristics of a certain state itself matter for its capacity. As states compete for labor and territory, characteristics of surrounding states are relevant. Thus, we take the baseline regression specification and add variables capturing relevant characteristics of a state's neighbors. Results are reported in Table 5, where we add an additional set of neighbor characteristics to the baseline specification in each column. All in all, while neighbor characteristics somehow reduce the size of the coefficient of caloric observability to about 0.16, this is still a large and economically and statistically significant effect. Interestingly, the results imply that neither the caloric suitability nor the caloric observability of the neighbor states has a significant impact.

However, states surrounded by small states are significantly larger than states surrounded by large states (as shown by the negative and significant estimate of the neighbor states area and the positive coefficient of the number of neighbor states). It also seems to be the case that states were larger when their neighbors did not have access to nearby major rivers while the opposite is true for access to resources. Thus, states have profited from having resource-rich states as neighbors, but were better off if their neighbors were further away from important transportation networks.

One important implication of our theoretical argument is that caloric observability should only matter for state size during the medieval period as later on, the scale effect becomes more and more important. To see whether this is the case, we run two types of regressions.

First, we interact the caloric suitability index with year dummies and look at how the effect of

caloric observability develops over time (Table 6). We find that, while the interaction terms are predominantly significant, in line with our expectations, the coefficient notably declines after 1556.

Table 5: *Observability of Agricultural Output and State Size—Controlling for Neighbor Characteristics*

Dependent Variable	ln(Area)			
	(1)	(2)	(3)	(4)
ln(Caloric Observability)	0.238***	0.204***	0.194***	0.171***
	(0.0564)	(0.0527)	(0.0518)	(0.0504)
ln(Neighbor Caloric Observability)	-0.0561	0.0304	-0.0169	0.0722
	(0.0758)	(0.0684)	(0.0708)	(0.0791)
ln(Neighbor Caloric Suitability)	0.409***	0.182	0.208	-0.357
	(0.145)	(0.135)	(0.135)	(0.251)
ln(Neighbor Area)		-0.0592***	-0.0468**	-0.00534
		(0.0220)	(0.0213)	(0.0235)
Number of Neighbor States		0.114***	0.115***	0.110***
		(0.0240)	(0.0240)	(0.0240)
Neighbor Mean Distance to Trade Routes			-0.00377*	-0.00242
			(0.00201)	(0.00231)
Neighbor Mean Distance to Roman Road			-0.00294***	-0.00184
			(0.00110)	(0.00185)
Neighbor Mean Distance to Large River			0.00559*	0.00575*
			(0.00291)	(0.00293)
Neighbor Mean Distance to Gold				4.37e-06
				(2.69e-06)
Neighbor Mean Distance to Silver				-1.19e-06
				(1.33e-06)
Neighbor Mean Distance to Copper				-4.53e-06**
				(2.28e-06)
Neighbor Mean Distance to Iron				-2.96e-06
				(2.02e-06)
Neighbor Mean Distance to Pottasium Salt				-3.11e-06**
				(1.27e-06)
Neighbor Mean Distance to Rock Salt				-2.26e-06
				(1.39e-06)
Neighbor Mean Distance to Lead Resev				7.48e-07
				(2.16e-06)
Neighbor Mean Relative Cereals Suitability				9.97e-05***
				(3.45e-05)
Neighbor Share of Luvisol Soils				-0.110***
				(0.0415)
Baseline Controls	✓	✓	✓	✓
Observations	1,842	1,842	1,842	1,842
R^2	0.679	0.735	0.738	0.746

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. Baseline controls include year and state type dummies, the basic geography, soil and climate, economic factors and resources controls as well as battles per area.

Table 6: *Temporal Evolution of the Effect of Observability on State Size*

Dependent Variable	ln(Area)			
	(1)	(2)	(3)	(4)
COI*1250	0.256***	0.144**	0.179**	0.232***
	(0.0598)	(0.0598)	(0.0824)	(0.0593)
COI*1378	0.250***	0.153**	0.317***	0.226***
	(0.0626)	(0.0620)	(0.0751)	(0.0608)
COI*1477	0.319***	0.192***	0.327***	0.297***
	(0.0668)	(0.0649)	(0.0947)	(0.0663)
COI*1556	0.293***	0.149**	0.322***	0.238***
	(0.0639)	(0.0668)	(0.0921)	(0.0634)
COI*1648	0.187**	0.0692	0.253**	0.176**
	(0.0767)	(0.0777)	(0.104)	(0.0768)
COI*1789	0.201**	0.0484	0.225**	0.166**
	(0.0846)	(0.0838)	(0.100)	(0.0832)
Baseline Controls	✓	✓	✓	✓
1150 State Dummies	–	✓	–	–
Share Early Settled & Forest Area	–	–	✓	–
Modern Country Dummies	–	–	–	✓
Observations	1,925	1,866	990	1,925
R^2	0.683	0.709	0.671	0.693

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. Baseline controls include year and state type dummies, the basic geography, soil and climate, economic factors and resources controls as well as battles per area.

Table 7: *Observability of Agricultural Output and State Size—Cross Sections*

Dependent Variable	ln(Area)					
	(1)	(2)	(3)	(4)	(5)	(6)
Year	1250	1378	1477	1556	1648	1789
ln(Caloric Observability)	0.209***	0.213***	0.252**	0.358***	0.120	0.104
	(0.0763)	(0.0737)	(0.106)	(0.0811)	(0.118)	(0.135)
Baseline Controls	✓	✓	✓	✓	✓	✓
State Type Dummies	✓	✓	✓	✓	✓	✓
Observations	368	402	313	367	255	220
R^2	0.665	0.688	0.704	0.698	0.736	0.751

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. Baseline controls include state type dummies, the basic geography, soil and climate, economic factors and resources controls as well as battles per area.

Second, we run separate cross-section regressions for each of the six years in our data set (Table 7). Here, the coefficients of caloric observability are highly statistically significant and vary between 0.2 and 0.33. Again confirming our theoretical reasoning, in 1648 and 1789 the coefficient of caloric observability is not significant and is notably smaller in size.

Table 8 reports a horse race between the scale effect (measured by a states average area in the two last periods) and caloric observability. We compare the times before and after the structural changes to the end of the Middle Ages, using our data points 1477 and 1789. Geographic area in earlier periods predicts state size in both estimations. However, in 1477 caloric observability determines state size significantly, and even has a larger effect than lagged area. In 1789, the lagged area shows a very high coefficient of around 0.9 while caloric observability is insignificant. These results confirm that state size at the end of the Middle Ages depends on caloric observability, but it explains modern state size only indirectly—via the state size achieved in earlier periods, presumably locked in by increasing returns to scale.

Table 8: *Determinants of State Size—Caloric Observability vs Scale Effect*

Dependent Variable	ln(Area)	
	(1)	(2)
Year	1477	1789
ln(Caloric Observability)	0.247**	0.0493
	(0.101)	(0.0694)
ln(Average Area 1250-1378)	0.0444***	
	(0.00786)	
ln(Average Area 1556-1648)		0.886***
		(0.0364)
Observations	313	163
R^2	0.731	0.962

Notes. Standard errors clustered on state-level are reported in parentheses. Coefficient is statistically different from zero at the ***1 %, **5 % and *10 % level. The unit of observation is a state. All regressions include a constant not reported. Baseline controls include state type dummies, the basic geography, soil and climate, economic factors and resources controls as well as battles per area.

VI. Conclusion

This paper has studied the determinants of tax capacity in medieval Central Europe. Because the HRE was a federation of states for hundreds of years, we have been able to connect the location, history and geographic circumstances of hundreds of states via our model. We have shown theoretically and empirically that the observability of agricultural output, via its impact on taxation capacity and the political structure of states, was a primary determinant of state size and survival in medieval Central Europe. We employed the theory of incomplete contracts to shed light on the dynamics of state capacity, before revolutionary social and economic events, from 1496 onwards, changed the game.

Our results provide evidence for the interaction of agriculture, climate, and geography in explaining political outcomes such as state capacity or regime. This adds a new perspective to the existing large and influential literature that links geography, climate and agriculture to long-run differences in economic outcomes (Diamond, 1999; Olsson and Hibbs, 2005). We have proposed a GIS measurement of observability of agricultural output that actually measures the degree of information asymmetry in an early society. As this index is well grounded in theoretical economic reasoning, it is potentially useful for other research endeavors in economic history, and long-run development.

This paper is a starting point for important further analyses—for example, why agricultural observability lost its explanatory power for state capacity during the early-modern period. This step would improve our understanding of the dynamics of state capacity in Europe over the last 1000 years. Potential factors to examine are the increased impact of technological innovations (e.g, De la Croix et al., 2017), or advances in education during the Reformation (Dittmar and Meisenzahl, 2017)), which led to increased urbanization and reduced a state's dependence on agricultural output for revenue. There are also opportunities for further study of the role of this observability mechanism in single states and other regions of the world.

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A.1. Dependent Variable

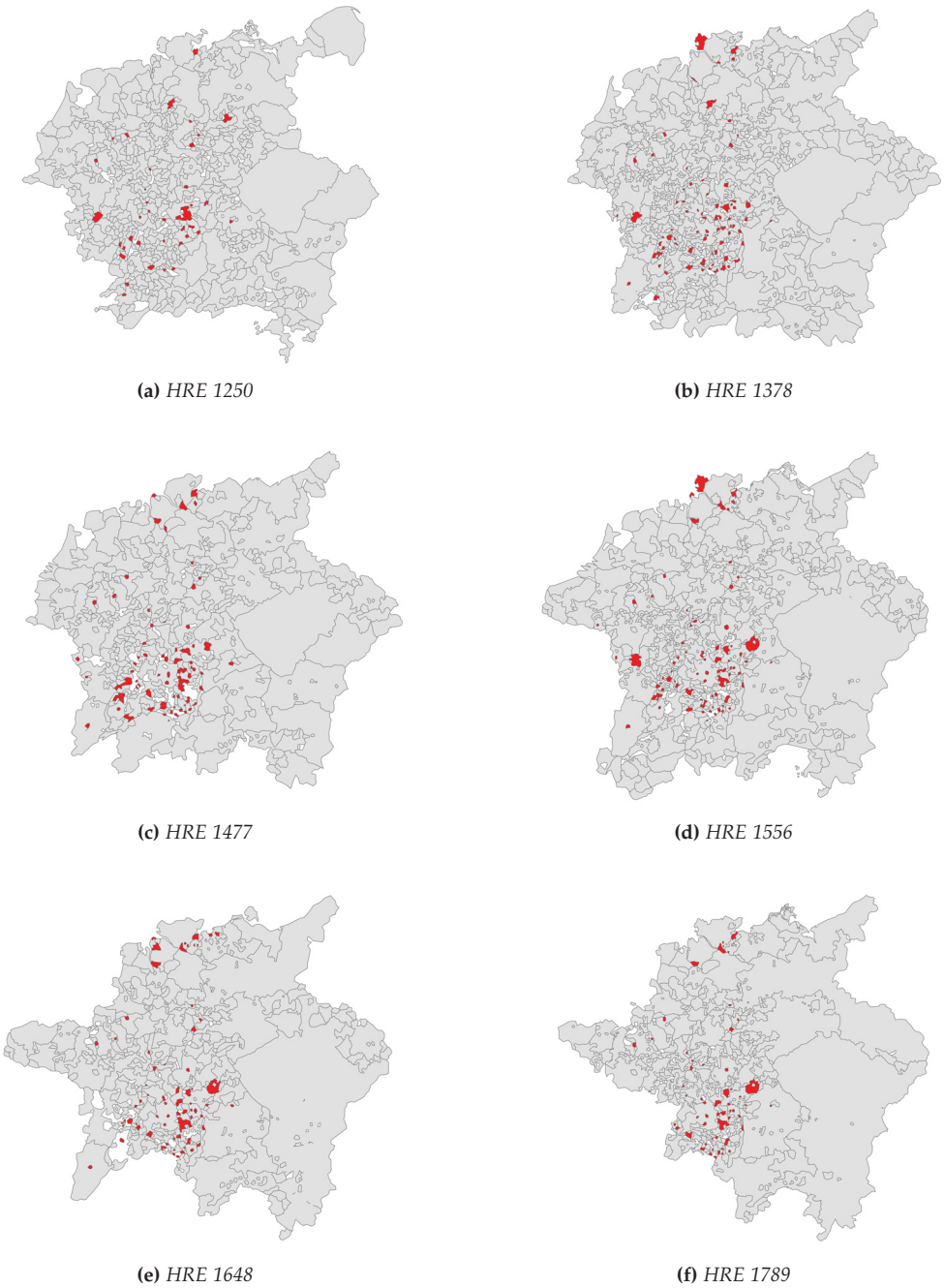
A.1.1. The Underlying Maps

The area of a state ("reichsunmittelbares Territorium") is calculated based on shapefiles created from maps of the non-Italian parts of the Holy Roman Empire printed in Wolff (1877). One of those maps, "Deutschland beim Tode Karl des IV. im Jahre 1378" ("Germany at the death of Charles IV. in the year 1378") is shown below in Figure A.1. Note that this map incorrectly includes the state of the Teutonic Order, so when digitizing the map we excluded this area. The maps are available here: `http://gei-digital.gei.de/viewer/javax.faces.resource/pdf-icon32.png.xhtml?ln=images/` (accessed on January 22, 2016).

Note: This figure shows the original map of the HRE as printed in Wolff (1877). For our empirical analysis we digitized this map using GIS software.

Figure A.1: *Germany at the Death of Charles IV. in the Year 1378 (Wolff, 1877)*

A.1.2. States in the Holy Roman Empire 1250–1789



(a) *HRE 1250*

(b) *HRE 1378*

(c) *HRE 1477*

(d) *HRE 1556*

(e) *HRE 1648*

(f) *HRE 1789*

Figure A.2: *The Holy Roman Empire and its territorial states (gray) and city states (red) at our sampling years*

A.1.3. Historical Background of the Sampling Years

(i) 1250 was the year of the death of Frederick II., the last Emperor of the Staufer dynasty. The Staufer dynasty had ruled the Empire as kings and emperors for more than 110 years. The whole dynasty (and with them central power) collapsed soon after, in 1254, when his only son Konrad IV., who was King of Germany but never Emperor, died. Following the collapse of the Staufer dynasty, a 20 year period called the "Great Interregnum" began, in which there was no elected Emperor but four elected kings. The kings were not universally accepted by the powerful princes, and so did not rule the Empire. In this period, known as an age of insecurity, violence and anarchy, many of the numerous city state (free and imperial cities) emerged and political fragmentation increased further[59].

(ii) 1378 was the year Emperor Charles IV died. This year marks the peak of the political fragmentation of the Empire—a situation that was made permanent by the Golden Bull of 1356. Furthermore, while considered by some as one of the greatest and most influential medieval German Emperors, he failed to preserve the powerful position of his dynasty, the Luxembourgians, as he pledged away a lot of the territories under his control, in order to pay his large debts. This further weakened central authority and helped to increase the political fragmentation of the Empire.

(iii) 1477 was the year in which Charles the Bold, Duke of Burgundy died. With his death, the Duchy of Burgund, one of the largest states in Europe, which could be considered an independent, middle-sized power (although de jure part of the HRE), collapsed and was split after violent hostilities. Some parts of the Duchy fell to France and the remainder was integrated into the HRE as smaller political entities (like the Duchy of Brabant). Furthermore, through marriage, the Habsburgs gained control over the remaining parts of Burgundy and thus, the death of Charles the Bold was the decisive event in the ascent of the House of Habsburg to world power. A period with slowly declining political fragmentation began.

[59] Political fragmentation in the 13th century was already much higher than during the 12th century. This was due to the fact that, as a consequence of the struggle between Henry the Lion, Duke of Saxony and Emperor Frederick I., the old and quite large stem duchies ("Stammesherzogtümer") were dissolved and partitioned into smaller (and even further divisible) territories. This should have weakened the position of dukes and princes towards the Emperor and hence strengthen central power, but in the long-run, had the opposite effect.

(iv) 1556, the year after the peace of Augsburg settled the confessional division of Germany for the next decades and ended the first wave of religious wars in the Holy Roman Empire. However, it also was the year when Charles V, probably the most powerful European monarch after the fall of Rome, abdicated from the throne due to his setback against the protestant princes and his lack of loyal vassals within the Empire. His reign marked the peak and turning point of the power of the House of Habsburg as his resignation from the throne and its defeat by the princes of the Empire was the starting point of the slow decline of the Habsburg's power.

(v) 1648, the year when the Thirty Years War ended, with the Peace Treaties of Westphalia. This lead to notable territorial changes, as some large and powerful states like Brandenburg or Hesse integrated smaller territories into their states. Furthermore, several imperial cities disappeared, becoming part of France or of Switzerland (whose independence was officially acknowledged). Finally, it settled the confessional question within the Empire.

(vi) (vi) 1789, the year when the French Revolution began and triggered a series of events and wars, resulting in the demise of the HRE and the most significant reshaping of the landscape of states in Central Europe since the dissolution of the stem duchies in the 12^{th} century.

A.1.4. De Facto vs. de Jure Independence of States in the Maps

City states are often among those territories for which it was not absolutely clear what degree of independence they had, regardless of their de jure status. It is well known that some cities had gained certain independence from their rulers, while never being officially considered as imperial cities. By the same measure, there were imperial cities that were never truly independent of their former ruler although they were granted "Reichsunmittelbarkeit" by the Emperor. We consulted standard sources on the history of German cities such as Köbler (1988) or Keyser and Stoob (1939–1974) and other studies on imperial cities, including Cantoni (2012) and followed their judgement about whether a city was de facto, and not just de jure, an imperial city. This is also an issue for several territories that were ruled by the Emperor or another high-ranked noble (like an elector) but where never part of their core territory. Two of these territories were the magraviates of Ober- and Niederlausitz (Upper and Lower Lusatia). Hence, some historians argue that the

power of those rulers over the territory was limited if non-existent. Therefore, we decided to treat the Lausitz territories as independent states.

A.1.5. Coding Example of a Difficult Case

A difficult of a different case to code is the county of Sponheim which consisted at the beginning of the 14th century, of two separated territories, the "Vordere" and "Hintere" Grafschaft of Sponhein. When the dynasty ruling the "Vordere Grafschaft" (the front county) died out, one fifth of the County went to the Electoral Palatinate and four fifth to the Count controlling the "Hintere Grafschaft" (the back county). After 1437, the Margrave of Baden and the Count of Veldenz inherited both parts of the County. Both rulers decided not to split the County but to rule it together as a condominium. Another change occurred in 1559, when the Princedom of Pfalz-Simmern (who had inherited the part of the County of Veldenz) bought the Electoral Palatinate's shares in the "Vordere Grafschaft". Simultaneously, it decided to give away the half of the "Hintere Grafschaft" to the Duchy of Pfalz-Zweibrücken. This resulted in the following situation: the "Vordere Grafschaft" belonged three fifths to Pfalz-Simmern (since 1559 Electoral Palatinate) and two fiftha to Baden. The "Hintere Grafschaft" belonged half to Baden and half to Zweibrücken. Finally, in 1707, the Margraviate of Baden-Baden and Electoral Palatinate split up the "Vordere Grafschaft" and in 1776, the "Hintere Grafschaft" was split in half by the Margrave of Baden and the duke of Pfalz-Zweibrücken. After 1815 the territory was integrated into Prussia and disappeared. In 1477 and 1555, i.e. during the condominium, we decided to consider the whole territory as county of Sponheim. Wolff, in his 1556 map has assigned the four separate territories of the county to either Pfalz-Simmern or Baden-Baden, Pfalz-Zweibrücken and the Electoral Palatinate. One cannot be sure whether he has assigned it to Pfalz-Simmern or Baden-Baden as both have the same color. In addition, this does not reflect the actual situation in 1556 (according to our sources), rather this is the situation in 1559 (when one assumes that he has assigned the "Vordere Grafschaft" to Baden and not to Pfalz-Simmern). For 1648 and 1789 we follow Wolff, who no longer included the county of Sponheim but assigned its territory to Pfalz-Zweibrücken, Electoral Palatinate and Baden-Baden (or Baden, respectively).

A.2. Control Variables

The spatial datasets were each converted into WGS 1984 UTM 32N projection. State type and "State in 1150" dummies are calculated from the shapefiles of Wolff's maps (1877). This is also the case for the variable "Outer Boundary" reporting the share of a states' border that is an outer boundary of the HRE.

Area Types. We have computed the (natural logarithm of the) area within each state that consisted of forests, swamps and floodplains (in m^2) in the pre-modern period and hence was very likely not settled or used for agricultural purposes. Floodplains and swamps might also have played a role as source of germs and diseases. Data is taken from a map by Schlüter (1952) that we have digitized. His map only covers the area of contemporary Germany.

Average Terrain Ruggedness. Following Riley et al. (1999) average ruggedness of a states' territory is calculated as the negative value of the derivative of the ruggedness index of a digital elevation model. The calculations are based on the elevation raster of Nunn and Puga (2012) (see above). Terrain ruggedness was calculated using QGIS.

Average Temperature. Historical average temperature for a state is taken from the data set of Guiot and Corona (2010). They constructed a grid cell database of historical European temperatures and their deviations from the average temperature in 1960–1990. We use this data set to calculate, for each state, the average temperature deviation in the period from 800 to 1378. To calculate the average temperature deviations for each grid we follow the interpolation procedure of Anderson et al. (2016) by filling in missing values with the inverse distance weighted average temperature of the twenty-four nearest neighbor grid points.

Battles. Number of battles per km^2 that have taken place in a state in the period between two of our maps (e.g. between 800 and 1250 between 1250 and 1378, between 1378 and 1477 etc.). Information of the date and location of the battles is taken from Bradbury (2004), Clodfelter (1992) and Darby and Fullard (1978).

Distance to City State. Distance to city states is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euclidean distance

from each of the 1,000 points per state to the closest Imperial city was calculated. In a last step, these distances were aggregated by state. The location of city states follows the maps of Wolff (1877) but we have corrected/ supplemented them—if necessary—with information from Köbler (1988), Keyser and Stoob (1939–1974) and Jacob (2010).

Distance to Major Rivers. Distance to major rivers is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euclidean distance from each of the 1,000 points per state to the to the closest major river (see Figure A.5) was calculated. In a last step, these distances were aggregated by state. For the location of the rivers, we used the dataset for 'WISE large rivers' shapefile, which can be downloaded here: `http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes`(last accessed May, 30th 2016).

Distance to Natural Resources. We have calculated seven variables reporting the distance to natural resources (copper, gold, iron, lead, potassium salt, rock salt and silver). Distance to natural resources is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euklidean distance from each of the 1,000 points per state to the closest deposit of the respective natural resource was calculated. In a last step, these distances were aggregated by state. The location of natural resource deposits is taken from Frenzel (1938) and Elsner (2009).

Distance to Roman Roads. Distance to (minor and major) Roman roads is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. In a second step, the Euclidean distance from each of the 1,000 points per state to the to the closest Roman road was calculated. These distances were aggregated by state. Locations of Roman roads (minor and major) originate from a shapefile included in the "Digital Atlas of Roman and Medieval Civilizations" (McCormick et al., 2013). The shapefile is based on the map of Roman roads in the Barrington Atlas of the Greek and Roman World (Talbert, 2000). It can be downloaded here: `http://darmc.harvard.edu/icb/icb.do?keyword=k40248&pageid=icb.page601659` (last accessed September, 24th 2015).

Distance to Medieval Trade Road. Distance to medieval trade routes is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. The Euklidean distance from each of the 1,000 points per state to the to the closest medieval trade route was calculated. In a last step, these distances were aggregated by state. Location of trade routes are obtained by digitizing a map on "Medieval Commerce" from Shepherd (1923). The map can be downloaded as pdf from here: `https://www.lib.utexas.edu/maps/historical/shepherd/europe_mediaeval_commerce.jpg` (last accessed July, 10th 2017).

Distance to Trade Fairs. Distance to trade fair is calculated as follows: Points with random location were generated until 1,000 points fell in into each state. The Euclidean distance from each of the 1,000 points per state to the to the closest trade fair city was calculated. These distances were aggregated by state. The locations of the fairs were taken from Ditchburn and Mackay (2002).

Maximum Elevation. Maximum elevation of each state in meters. Data is based on the Digital Elevation Model (DEM) of the U.S. Geological Survey's Center for Earth Resources Observation and Science (EROS), namely the GTOPO30 dataset, which can be downloaded here `https://lta.cr.usgs.gov/GTOPO30` (last accessed May, 30th 2016). The GTOPO30 has a spatial resolution of 30 arc seconds.

Plough Suitability. Plough suitability of a states' soils are measured by the share of its area which has luvisol soils. Data on location of luvisol soils is taken from the European Soil Database version 2 provided by the European Soil Data Center (ESDAC). We used the 1km*1km raster data set downloadable here (upon request): `http://esdac.jrc.ec.europa.eu/content/european-soil-database-v2-raster-library-1kmx1km` (last accessed June, 20th 2017).

Pre-Historic Settlement Area. We have computed the (natural logarithm of the) area within each state that was already settled in pre-historic times (in m^2). This information stems from Schlüter (1952).

Latitude. Minimum longitudinal coordinates a states' centroid (mid-point) in meters. Calculated

using QGIS.

Longitude. Minimum longitudinal coordinates of a states' centroid (mid-point) in meters. Calculated using QGIS.

Relative Cereals Suitability. An index of caloric suitability of cereals relative to roots and tubers for each states was generated according to the logic of Mayshar et al. (2015) using data from Galor and Özak (2015). This index measures the difference between the maximum yield from plants that are appropriable, and the maximum yield from roots and tubers. Appropriable plants ("cereals") included alfalfa, banana, barley, buckwheat, cabbage, canary grass, chickpea, citrus, coconut, cow pea, dry pea, flax, foxtail millet, greengram, indigo rice, jatropha, miscanthus, oat, oil palm, olive, pasture grass, pasture legumes, pearl millet, pigeon pea, pulses, rape, rye, sorghum (subtropical), sorghum (tropical highland), sorghum (tropical lowland), soybean, spring barley, spring wheat, sugar cane, tea, wetland rice, wheat, winter barley, winter rye, and winter wheat. Roots and tubers were carrot, groundnut, onion, yams, and white yam.

Table A.1: *Descriptive Overview of the Data Set*

Variable	Obs	Mean	Std. Dev.	Min	Max
Area	1,925	2250000000.000	8470000000.000	4948171.000	193000000000.000
Average Temperature	1,925	0.150	0.054	-0.011	0.355
Battles per km^2	1,925	0.000	0.000	0.000	0.015
Belgium	1,925	0.040	0.196	0.000	1.000
Caloric Observability	1,925	399.880	475.622	0.000	4160.717
COI Post-1500-COI Pre-1500	1,925	3619.769	181.221	2145.383	4284.983
County	1,925	0.265	0.442	0.000	1.000
CSI Post-1500-CSI Pre-1500	1,925	1474.386	181.221	0.000	2139.601
Czech Republic	1,925	0.010	0.101	0.000	1.000
Distance to Copper Deposit	1,925	136088.000	62582.970	8989.408	394265.800
Distance to Gold Deposit	1,925	93655.510	70641.920	0.000	457256.300
Distance to Imperial City	1,925	65288.080	93232.030	0.000	509783.900
Distance to Iron Deposit	1,925	79611.300	54619.310	0.000	377603.900
Distance to Large River	1,925	33.660	23.005	0.888	143.924
Distance to Lead Deposit	1,925	116992.100	63723.760	8277.119	441320.800
Distance to Potassium Salt Deposit	1,925	121460.000	96965.100	0.000	597686.800
Distance to Rock Salt Deposit	1,925	130085.100	86606.360	18.912	376318.100
Distance to Roman Road	1,925	81.126	118.883	0.650	656.984
Distance to Silver Deposit	1,925	397472.600	140633.700	18386.710	810327.000
Distance to Trade Fair	1,925	231385.200	131436.600	3159.897	843413.800
Distance to Trade Route	1,925	45.722	37.628	1.169	236.214
Duchy	1,925	0.063	0.244	0.000	1.000
Ecclesiastical State	1,925	0.202	0.401	0.000	1.000
Electorate	1,925	0.025	0.158	0.000	1.000
France	1,925	0.081	0.272	0.000	1.000
Germany	1,925	0.707	0.455	0.000	1.000
Herrschaft	1,925	0.161	0.368	0.000	1.000
Hungary	1,925	0.001	0.032	0.000	1.000
Italy	1,925	0.008	0.088	0.000	1.000
Kindom	1,925	0.002	0.046	0.000	1.000
Lithuania	1,925	0.001	0.023	0.000	1.000
ln(Area)	1,925	20.067	1.650	15.415	25.988
ln(Caloric Observability Post-1500)	1,925	5.768	0.885	0.000	8.078
ln(Caloric Observability)	1,925	2.832	1.007	0.000	8.334
ln(Caloric Suitability Post-1500)	1,925	7.266	0.637	0.000	7.786
ln(Caloric Suitability)	1,925	7.431	0.679	0.000	7.897
ln(Floodplains)	990	2.069	6.712	0.000	23.821
ln(Forest Area)	990	6.220	8.415	0.000	17.594
ln(Optimal Caloric Observability)	1,924	6.662	0.975	0.000	9.716
ln(Optimal Caloric Suitability)	1,925	8.947	0.638	0.000	9.430
ln(Pre-Historic Settlement)	990	9.092	8.736	0.000	17.477
ln(Settled Area)	827	19.122	1.313	12.666	22.857
ln(Swamp Area)	990	2.145	6.666	0.000	22.836
Luxemburg	1,925	0.002	0.046	0.000	1.000
Margraviate	1,925	0.017	0.128	0.000	1.000
Maximum Elevation	1,925	767.721	766.672	5.000	4366.000
Netherlands	1,925	0.020	0.139	0.000	1.000
Outer Boundary	1,925	0.047	0.137	0.000	0.890
Poland	1,925	0.034	0.181	0.000	1.000
Princedom	1,925	0.054	0.225	0.000	1.000
Relative Cereals Suitability	1,925	17279.220	3039.148	0.000	20795.540
Republic	1,925	0.018	0.134	0.000	1.000
Share of Luvisol Soils	1,925	4.085	2.577	0.027	16.823
Slovenia	1,925	0.009	0.096	0.000	1.000
Switzerland	1,925	0.067	0.250	0.000	1.000
Terrain Ruggedness	1,925	112.777	141.549	2.212	858.629
Territories	1,925	1.722	1.755	1.000	21.000

A.3. Failure of States

(a) *Territories missing in 1378*

(b) *Territories missing in 1477*

(c) *Territories missing in 1556*

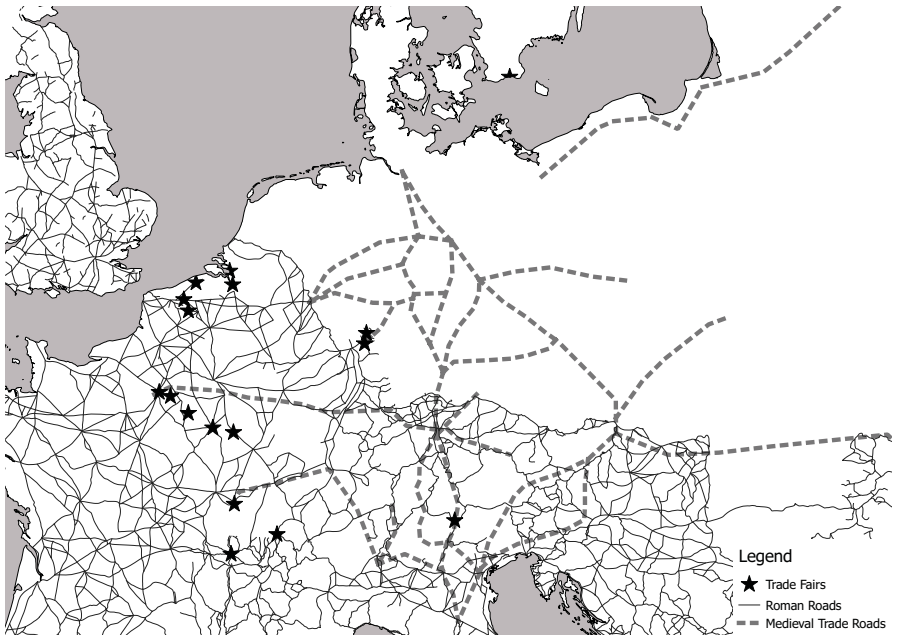
(d) *Territories missing in 1648*

(e) *Territories missing in 1789*

Note: The data on the failure of the states was collected from Köbler (1988) and completed from other sources on regional history

Figure A.3: *Failed states*

A.4. Geographic Controls

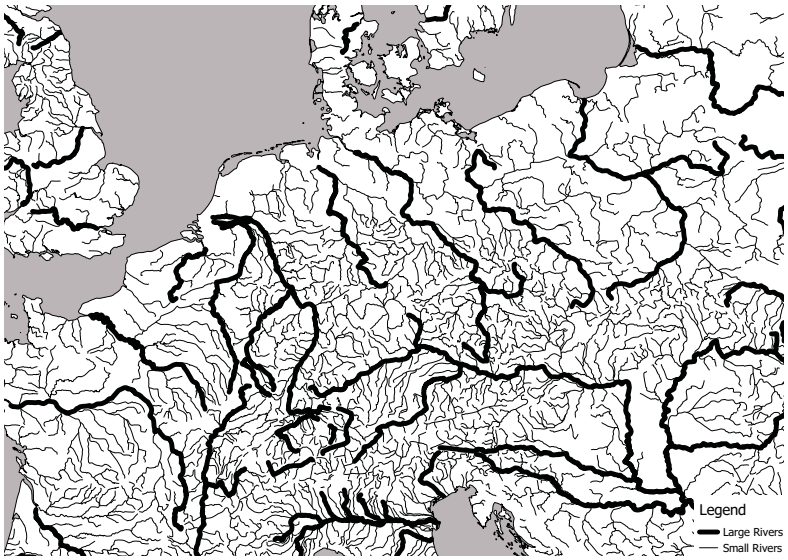


Note: Data on Roman Road was taken from McCormick et al. (2013), medeval trade routes were digitztized from Shepherd (1923). Trade fairs were digitized using modern positions and the towns from Ditchburn and Mackay (2002).

Figure A.4: *Roman & Medieval Roads, Trade Fairs, and Hanseatic Towns*

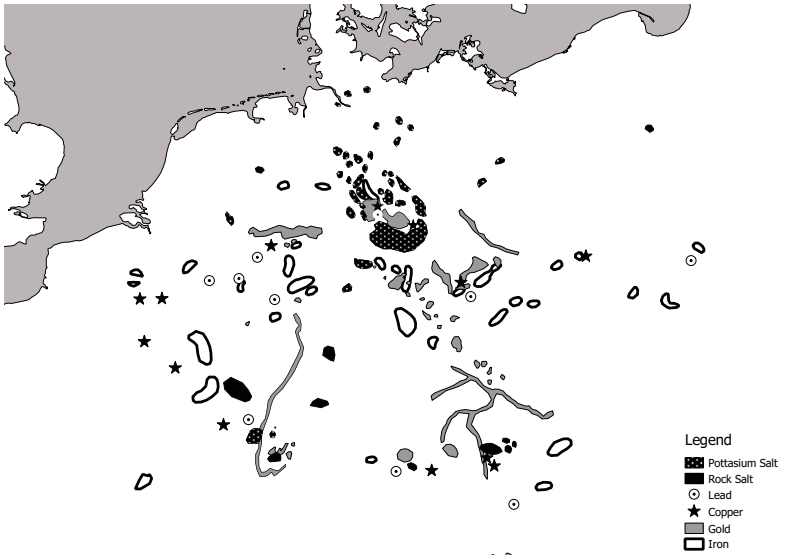
Table A.2: *Inclusion of the trade fairs*

Name	1250	1378	1477	1555	1648	1789
Antwerp	–	✓	✓	✓	✓	✓
Bar sur Aube	✓	✓	–	–	–	–
Bergen ob Zoom	–	✓	–	–	–	–
Bozen	–	–	✓	✓	✓	✓
Bruges	✓	✓	✓	✓	✓	✓
Chalons sur Saone	✓	✓	–	–	–	–
Frankfurt	–	✓	✓	✓	✓	✓
Friedberg	–	✓	–	–	–	–
Geneva	–	✓	✓	✓	✓	✓
Lagny	✓	✓	–	–	–	–
Leipzig	–	–	✓	✓	✓	✓
Lille	✓	✓	✓	✓	✓	✓
Lyon	–	✓	✓	✓	✓	✓
Provins	✓	✓	–	–	–	–
Skanes	✓	✓	✓	✓	✓	✓
St. Denis	✓	✓	✓	✓	✓	✓
Troyes	✓	✓	–	–	–	–
Ypres	✓	✓	✓	✓	✓	✓



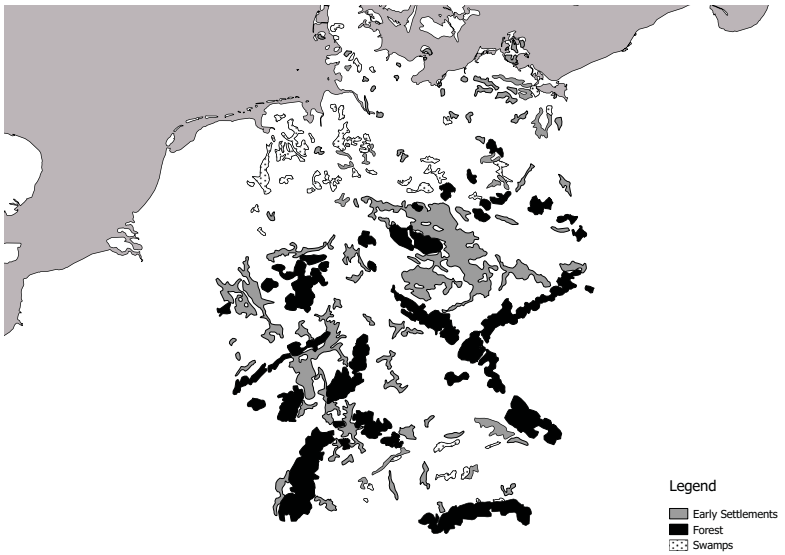
Note: Accessible via `http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes` (last accessed May, 30th 2016)

Figure A.5: *Large and Small Rivers*



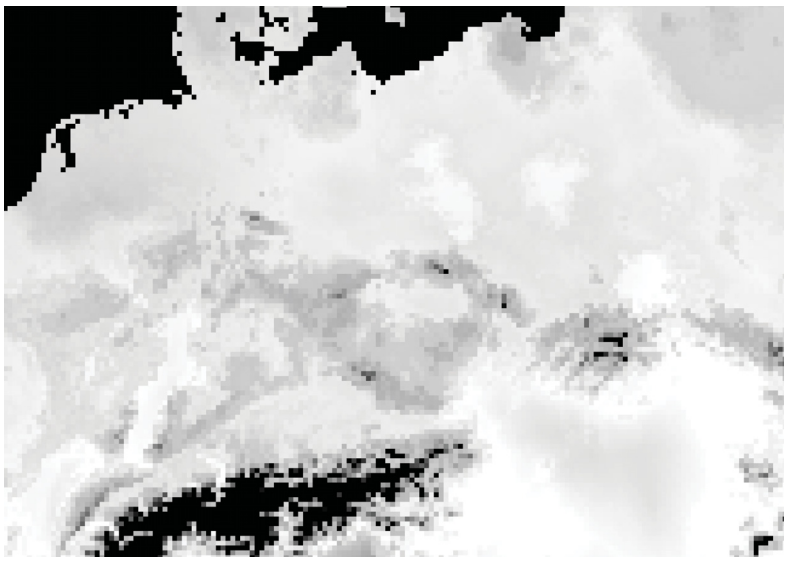
Note: These data were digitized from Frenzel (1938) and Elsner (2009)

Figure A.6: *Mineral Resources*



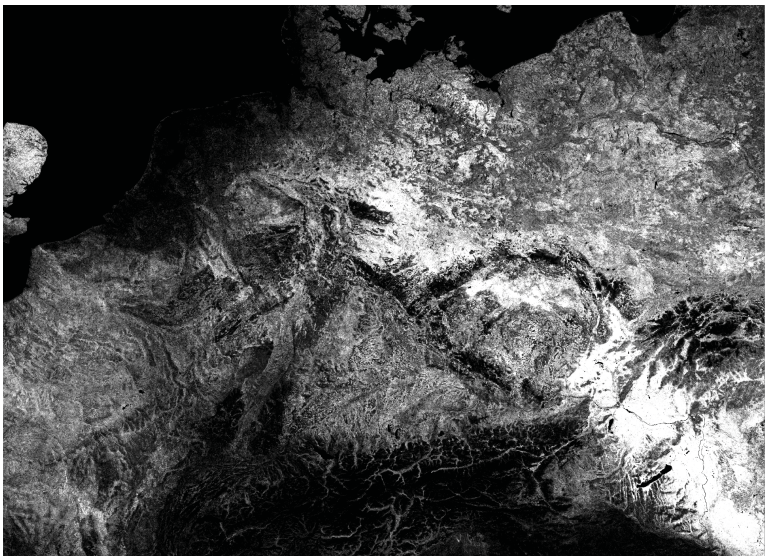
Note: Areas were digitized from Schlüter (1952).

Figure A.7: *Settlement in the Early Middle Ages*



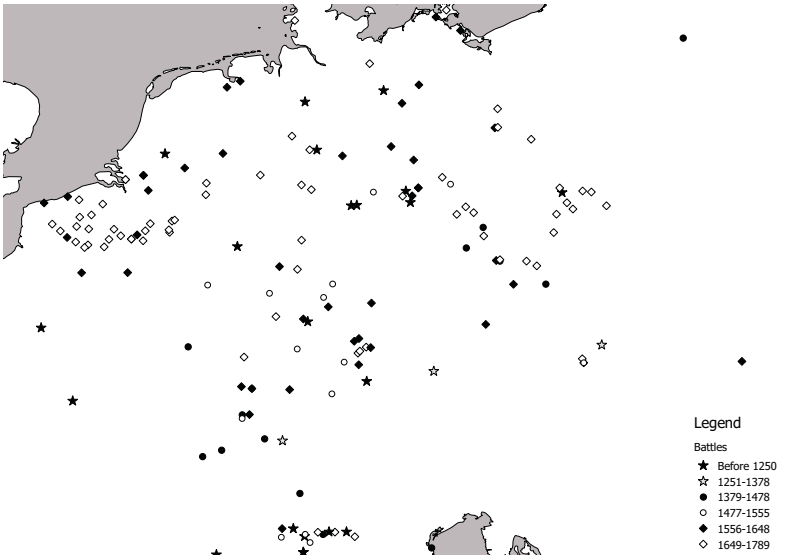
Note: Own calculation on the basis of Mayshar et al. (2015) and data from Galor and Özak (2014, 2015). The lighter the colors, the higher is suitability for growing cereals relative to growing roots and tubers.

Figure A.8: *Cereals vs. Roots and Tubers*



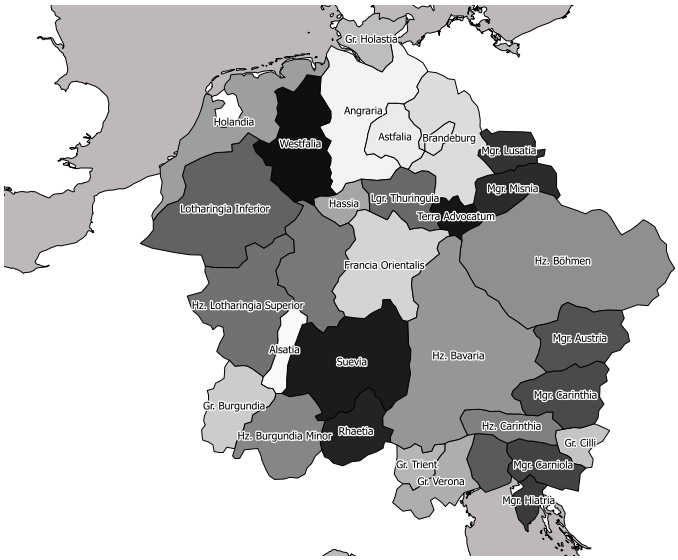
Note: The instrument from Alesina et al. (2013) shows only minor variation within our sample. We employ the idea by Andersen et al. (2016) based on data from Panagos (2006) and Van Liedekerke et al. (2006).

Figure A.9: *Usage of the Heavy Plough Alesina et al. (2013); Andersen et al. (2016)*



Note: Information of the date and location of the battles is taken from Bradbury (2004), Clodfelter (1992) and Darby and Fullard (1978).

Figure A.10: *Battles*



Note: Digitized from Wolff (1877)

Figure A.11: *Regions of the HRE in 1150*

The State Built on Sandy Grounds: How Geography formed Brandenburg-Prussia

Thilo R. Huning*

Abstract

To further understand the link between taxation and the formation of state capacity, this paper employs an incomplete contract model of an agricultural society. Using province-level data of Brandenburg-Prussia from 1650–1697, I argue that the origins of it's success lie in 17th century institutional reforms and geography, rather than the genius of its princes. These reforms affected predominantly the rural parts of Prussia, integrated the provinces outside of Brandenburg, reduced the rents of the landed-nobility, and shaped their relationship towards the central state.

JEL Codes: *O42 · D73 · Q15 · N93 · D82*

Keywords: *State capacity · observability · principal-agent problem · taxation · Prussia*

Is Prussia[1] today a role model for the development of an effective state? Some have highlighted

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[1]The nomenclature for different Hohenzollern territories is very confusing when writing from a long-term historical perspective. For example, Clark (2007) is subtitled 'The Rise and Downfall of Prussia 1600–1947', while Prussia only became the name for the whole Hohenzollern lands in 1701. To fix terms, to the whole lands under the rule of the Hohenzollern, I will refer to as 'Brandenburg-Prussia' or 'the Electorate'. 'Prussia' stands for the Kingdom of Prussia 1701–1947. When I refer to the original Prussia, the most eastward province of the Hohenzollern lands, I will use the term 'Eastern Prussia', which is ahistoric but avoids confusion with the later Kingdom of Prussia.

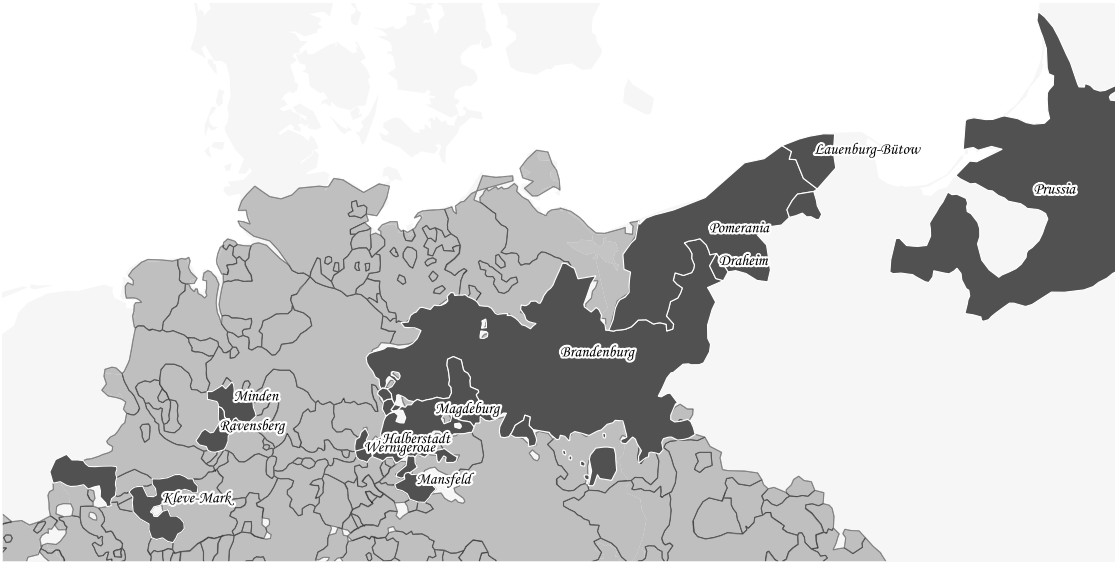
the ability of the Prussian state to provide public goods, especially security, and education[2]. Some have described Prussia's role as a shelter for outcasts, like the Huguenots (Hornung, 2014). Clark (2007) discusses the 'enlightened' values that the Prussian princes were guided by, pointing at the influence of spirit on economic outcomes (McCloskey, 2006; Mokyr, 2011). Others draw the picture of an authoritarian state that crowds out private investment and is inherently undemocratic (see Beck, 1997; Rosenberg, 1958). Gerschenkron (1966) famously blamed the Prussian authoritarianism for the rise of the Nazi party and was followed by a whole school of historians assessing a German 'special path'[3] that began in autocratic Prussia. What unifies both positions is the legacy of a strong state (Acemoglu, 2005). How did this state emerge?

Theories on the origins of states are based upon the idea that there is agricultural output that needs to be protected (Bates et al. (2002); North et al. (2009) and more recently Dal Bó et al. (2015); Boix (2015); Mayshar et al. (2015)). States are more efficient in providing security, or violence (Bean, 1973; Weber, 1919; North et al., 2009) than an individual. Therefore, either states emerge from stationary bandits (Olson, 1993) or a voluntary 'social contract'. This basic state collects taxes from its subjects and spends them on the provision of security. The effective provision of security, and the influence of military technology and its development on public order has been subject of many studies (Tilly, 1975; Boix, 2015; Gennaioli and Voth, 2015). Mirabeau's quote "While most states have an army, the Prussian army has a state" and today's memorial of Prussia's military, with its annual peak in New York City's Steuben parades, seem to underline the role of a strong military for a strong Prussian state.

Craig (1955) famously argued that it was the role of the army, first in Prussia and then in the German Empire, that inhibited the development of a German representative democracy in the Western tradition, destabilized the Weimar Republic, and supported the rise of the Nazi party. While refusing simplistic explanations for their success, "the theory that Germans are by nature subservient to authority, militaristic, and aggressive, and that there is very little that any one can do about this except deprive them of the means of making themselves dangerous to their neighbors" (p. xiii), Craig does not provide a theory of the origins of this military state. He argues

[2]Studies that argue for a strong effect of education for Germany's catch-up in the 19th century include Cinnirella and Hornung (2016), while Edwards (2013) has a critical view on this. Qualitative studies include Beck (1997), who argues that authoritarianism and the welfare state are interlinked and begins his historical narrative in the 1830s.

[3]Relevant studies include Jarausch (1983); Wehler (1987), among many others.



Note: This map, based upon the dataset from (Huning and Wahl, 2017) extended by the provinces out of the Holy Roman Empire from (Wolff, 1877) shows the position of the provinces legally part of the Hohenzollern lands ('Brandenburg-Prussia') within the Holy Roman Empire. The most Western province Mark-Kleve, originally two counties, borders today's Netherlands, while Eastern Prussia is today a part of the Russian Federation.

Figure 1: *Map of the provinces of Brandenburg-Prussia in 1672*

that the strong role of the military in Brandenburg-Prussia directly after the Thirty Years War survived the French Revolution and its aftermath, it also survived 1848, it united Germany in the heart of its enemy in 1871, it also survived the defeat of 1918, and it was the German military power and the people that dreamed of its renaissance that Hitler's speeches addressed. Therefore, the central aim of this paper is to find the origins of these developments. What explains the role of Brandenburg-Prussian army in the 17th century?

Historians agree that the time after the Thirty Years War saw an unprecedented increase in the regulation of society by states (see Whaley, 2012). It remains however in doubt why Brandenburg was more successful in creating such a strong state while other German princes failed. Ruling out a favorable geography as an explanation, many have highlighted the role of individuals. To provide a representative quote, Wilhelm von Humboldt assessed that "Prussia cannot be compared to any other country; it is bigger, and it not only wants to be bigger, than provided by its natural strength. There has to be an extra. [...] In the times of Fredrick II., it was his genius."[4]. Was the

[4]Own translation cited after (Haffner, 1998, p. 132)

strong Prussian state an outcome of its princes' genius, or preferences?[5]

The answer to this question potentially lies in regarding the other side of state finances, their income, taking advantage of the theory of incomplete contracts. Mayshar et al. (2017) have argued that Egypt could build a stronger state than Mesopotamia because its agricultural output was easier to assess. While the Nile brings with equally fertile soil, the influence of the Mesopotamian private channels on agricultural output are more complex. The more complicated tax assessment, the larger the information asymmetry between state and subjects, and the more costly tax administration. Central Europe's geography is yet more complicated. Huning and Wahl (2017) propose a geographic index, caloric observability, to quantify the extend of information asymmetries. It is based on geographic variation in the output of soil in terms of calories. The paper includes a model that links bad observability to uprisings and outmigration, but also to urbanization. This model is tested on a new data set on the Holy Roman Empire 1250–1789, and it finds that states with less observability are more prone to bankruptcy, are more long-lived, and in the long-term also geographically larger than states with bad observability. How do the idiosyncratic explanations for the Prussian state look in the light of this theory? What allowed the Hohenzollern to create the country with the highest taxes in Europe (Haffner, 1998, p. 95)?

The legacy of Prussian state capacity and its ability to reforms are almost exclusively built around the early 19th century reforms. In today's Germany, the names of Stein, Hardenberg, Humboldt, and other reformers of the 19th century are ubiquitous, while the legacy of the reformers of the 17th century, which I will argue are key to the development of the state and a prerequisite for all following reforms, are forgotten. This general notion holds for recent economics literature. While Acemoglu et al. (2011) and Kopsidis and Bromley (2016) discuss whether the reforms in the Western part of Brandenburg-Prussia are a result of French shock reforms, Cinnirella and Hornung (2016) investigate empirically the effects of the nineteenth century reforms. In contrast, I am unaware of any quantitative studies on earlier reforms, which are essential to the becoming

[5]Many studies view the origin of Prussian militarism in the reign of prince Frederick William (1688–1740) (Clark, 2007, p. 95). He is usually associated with a fetish for uniforms in general, but especially with tall men in uniform, the 'Lange Kerls' ('tall lads') which were conscripted all over Europe. Other highlight the role of Friedich II., especially his shift from enlightened ideas presented in his book 'Antimachiavell' (1740) to the exact opposite politics in the unlawful annexation of Silesia in the same year. Some go as far as regarding these wars as a way of emancipating from childhood traumata, including the execution of his friend Hermann von Kathe, which he had to witness (see Clark, 2007, p. 110). Building upon the study of the vast autobiographic material, others have assessed his general suicidal and risk-seeking behavior.

of an administration and state. The genius of Frederick 'the Great' becomes less staggering once one regards the war chest he inherited from his father (Haffner, 1998), and in parts our hindsight knowledge on the influence of human capital accumulation on growth (Galor, 2011; Becker and Woessmann, 2009) shifted our focus away from the creation of efficient taxation towards state expenditure on schooling as well as structural change, and blocks our view on the inheritance the 19^{th} century Prussian bureaucrats retrieved.

The remainder of this paper is structured as follows. I will outline some theoretical considerations that extend the model from Huning and Wahl (2017) and guide the descriptive and comparative analyses. This is followed by an overview of the development of state capacity in Prussia 1600–1804. The influence of geography upon Prussia is then studied in light of this model using break points in Prussian history, before concluding.

I. Theoretical Considerations

Huning and Wahl (2017) extend the closed economy model in Mayshar et al. (2017) by introducing interstate competition. They argue with Carneiro (1970) and Volckart (1997, 2002) that this competition was not only about war, but mostly about who could attract most migrants, increasing the population of their country. They highlight the role of Imperial cities, mostly in the South and West of the Holy Roman Empire, which were a common destination for outmigration, and could not be pursued to send fleeing peasants back to their home lands.

In the largest territory of the Holy Roman Empire, Habsburg-Austria, the level of this competition differed enormously within its provinces. While the vast Austrian hinterland was far away from Imperial cities and also other states to compete for migrants with, their Western border faced strong competition (Ogilvie, 2001). Due to the fact that many Imperial cities have Roman roots and were therefore far away from the Germanic and Slavic settlements that became Brandenburg, competition with Imperial cities was rather low. However, the large supply of land in the territory of the German order imposed the risk that Brandenburg peasants outmigrated if they felt treated unfairly and hear about a 'better' place. Unfair treatment, as already argued by Mayshar et al. (2017) does in the long-run not depend on personal characteristics of rulers, but on their ability to

observe output correctly. If they overestimate the outcome of the harvest due to a screwed signal induced by complex geography, which may cause rulers to overtax their subjects. This might force subjects to starve (if they do not migrate).

1. The Military State?

A central swift for the development of the European states has been attributed to changes in tactics and military administration, as a consequence of the introduction of gun powder (see Rogers (1995) for an overview). These led to decreasing marginal costs of the provision of defense as a public good, and therefore favor larger states. As outlined in Blanning (2007, p. 289f.) when comparing the army sizes in the 150 years after the Thirty Years War, a bifocal development becomes apparent: While smaller German states, including Saxony and Bavaria experience a decrease of their army sizes, the largest states in Europe experience a sharp increase. Saxony reaches its peak at the beginning of the 17^{th} century, at 30,000 soldiers, and is left with only around 6,000 in 1792. Bavaria's army was halved in the same period. In the same time, the army of Brandenburg-Prussia, only 4,650 men strong in 1643 would rise to 45,000 in 1678, and no less than 30,000 in peace time 1688. These numbers would be rising steadily. In 1786, just before the French Revolution, the Prussian army was almost 50,000 men stronger than the French. Before the First Silesean War (1740–1742), Prussia would be able to spend 80% of its state revenue on military purposes, more than any other state in Europe (Hassinger, 1971). How was this possible, given the smaller population, the heterogeneous political traditions and internal rivals of a central state (burghers, nobility) and competition with other states?

The model in Huning and Wahl (2017) represents state capacity as an equilibrium outcome between efficient provision of security (using military technology) and taxation. Security is the origin of state, and therefore the first public good to be provided (Bean, 1973; Olson, 1993; Boix, 2015). I understand the term 'Military State' as a government, a stationary bandit, or a voluntary agreement who institutionalized an administration independent and impersonal of the actual ruler, so that a minimal level of state capacity has been reached, but public goods are almost exclusively provided by the military. Such a military state, by outsourcing the provision of public goods other than security can transform into other forms of a 'strong state' for example a welfare

state (Beck, 1997), but also autocracy (Rosenberg, 1958). As argued by Frost (2000), the idea of a strong, centralized state based on central provision of security was a Swedish invention which has been imported during the Thirty Years War. Frost argues that Sweden in the 1600's suffered from a low agricultural productivity, and a large but impoverished nobility. This poverty, he goes on, had two consequences. It allowed the Swedish king to exploit the weak position of the nobility to muster them into his army. Second, it forced Sweden into a spiral of wars in search of revenue. Frost concludes that the paradox of poor Sweden becoming a premodern power has to be interpreted as a sign of struggle rather than glory, and also as the nucleus of the premodern military state. The conditions under which Swedish troops entered Brandenburg-Prussia allowed the export of this military state, first in areas with a weak nobility (as in Sweden). There was no land under Hohenzollern rule, and no other German land of considerable size, which was more apt to introduce these reform than the Mark of Brandenburg. Its plain, and uniform geography prohibited large rents by nobility, and eased the import of this new form of state.

A state with a favorable geography would be able to afford the initial payment to start a self-reinforcing process of the military state. Jones (2003, p. 105) argues with Ardant (1975) that the core of such state has to be its most fruitful area, such as the Paris or London Basin, or the Po Valley. Following Mayshar et al. (2017), we see that a soil generating surplus is a necessary, but not a sufficient condition for a tax base. It might be, and I will argue how this idea has explanatory power for the developments in Prussia-Brandenburg, that a high observability of output compensates the effect of a bad soil. Once a certain level of state capacity, due to military spending and administration, is reached, it can under circumstances extend using recursive reasoning. As summarized by Haffner (1998, p. 103), militarism drove both Prussia's demand for immigration and an increase in taxation; high military spending called for high taxes, immigration, and administrative capacity, which allowed further militarization, and so on. The observation that taxes introduced to finance one time expenditures remain, especially wars, has been coined the 'ratchet effect' of public finance (Peacock and Wiseman, 1961; Rasler and Thompson, 1983). In line with theory, this effect should not only relate to the level of taxes raised from a region, but also the effect of observability on regions. If a state, in desperate need for finance for defense, creates a larger administrative capacity, this capacity might survive the war. Since defense from outsiders is

the most basic government function (Bean, 1973), spending on fighting an existing danger faces the lowest resistance.

2. The Way to the Central State

Brandenburg-Prussia emerged from the fusion of Prussia in Poland, the princedom of Brandenburg in the Holy Roman Empire, and also other territories scattered across the Empire. They featured distinct political orders which existed in parallel, and affected each other with the increasing role of central administration. Huge increases in land, came with a jump in population, potential revenues for taxes, but also an enormous increase in the length of the border to be defended. For the perspective of a single province that enjoyed relative independence before, giving up this independence comes with trade-offs indicated by literature on the sizes of states (see Alesina and Spolaore (1997); Bolton and Roland (1997), and Spolaore (2014) for an overview). Some provinces might find it beneficial to continue paying for their own defense, and also collect taxes to do so autonomously. This matter becomes increasingly interesting once the existing tax collection is also legitimated via representative assemblies. If these assemblies' interest would be perfectly aligned with the interest of all citizens of their province, any centralization of authority in Berlin would lead to a decrease of the legitimacy of taxation in general. Wahl (2015) argues that some German cities indeed had strong participative institutions already in the Middle Ages, which also fostered these cities' development. Therefore, a strong central outside government replacing tax collection and provision of public goods would lead to a reduction of participation. On the other hand, if assemblies suffer from a principal-agent problem, and their representatives have their own motives leading them to obstruct centralization. They would do so even if security could be objectively better and more efficiently provided from a central government. In such state, a more centralized state would not face a decrease in objective legitimacy. We would expect this kind of representatives of rent-seeking nobility in rural areas. The question of whether the centralization efforts in the 17^{th} century set Brandenburg-Prussia requires therefore a distinction between rural and urban areas. When we analyze the empirical results, a discussion of local differences in the structure of the economy is therefore essential to the discussion.

3. The Missing Urbanization

Huning and Wahl (2017) argue with Volckart (2002) that the urbanization rate is an endogenous variable. Rulers can allow, or forbid, their subjects to settle in cities, depending which would return the larger mount of taxes. State rulers would agree to their peasants to move to the cities, depending on their marginal product of labor, but also on the observability of their agricultural output. If Brandenburg was endowed with a soil that was exceptionally uniform and well to observe, it would not be surprising in the light of this theory to find that the urbanization of Brandenburg was relatively low, and is low to the day relative to other German regions. On the one hand, this reduced resistance from urban population and urban political entities, which would become a problem in other provinces. On the other, the low urbanization rate had negative impact on the development of Brandenburg, so that the Electors actively contracted so-called 'Locatores' to found towns (Abel, 1953). Other regions were more sparsely settled in general, such as Eastern Prussia, but included traditional trade-hubs (such as Danzig and Königsberg). These hubs, much in the way of Imperial cities, established their own forms of government, and would resist any form of intervention. Therefore, a careful analysis of the structure of settlement is important when assessing the effect of centralization for different regions of Brandenburg-Prussia with each other.

4. Hypotheses

Bringing these ideas of a state attempting to centralize taxation by administrative measures to the data, there are two main hypothesis to be tested.

H1. The role of observability for taxation increases. In this paper, I argue that the Hohenzollern administration collected military contributions from their provinces that were increasingly linked to their economic potential. Since provinces which could be taxed more effectively due to their favorable and more homogeneous geography, we expect that while caloric observability does not explain contributions at the beginning of the period, it does so at its end.

H3. A good observability assists the central government to centralize. A central government with

a better ability to observe agricultural output due to a favorable geography, should be more able to extract taxes, given that the resistance by the old estates is weak enough. In this case, the historical narratives of resistance that the Elector faced should be partly discounted. If this hypothesis holds, resistance by the old elites could have been overstated by national history, presumably to celebrate the Hohenzollern's vision on their mission to unifying Germany. This hypothesis seems plausible in the light that estates' savings from formerly extracted taxes should be depleted through the vast devastation of the Thirty Years war. Empirical results indicating *higher* contributions from the more observable regions would support this hypothesis.

II. Historical Background

1. Not An Empire?

When Voltaire famously assessed that the Holy Roman Empire was "neither Holy, nor Roman, nor an Empire", he pointed at the peculiar political fragmentation of German lands, surrounded by seemingly centralized European Great Powers. Its cause has been subject to long-standing debates.

One school, in the line of German nationalist historians like Treitschke (see Clark, 2007; Wilson, 2016, for an overview), view the cause in external powers creating a weak and impoverished German people in their aim to capture the European 'heartland' (Mackinder, 1904) (a reasoning that is going to reappear in the discussion on the Treaties of Versailles, the Dawes Plan, the NATO membership of reunified Germany, and the abolition of the Deutsche Mark. (Simms, 2013, Ch. I) lines out how first the Ottomans, then the French, followed by the Swedish, have invaded German lands, while the Habsburg failed at creating a unified home front.

To question this school's narrative, consider the heterogenous effects war had on the development of states. Many states, and these include Prussia-Brandenburg, were well able to centralize their power not despite, but because of war with outside forces points at internal problems of the Habsburg empire. The empirical analysis can attribute some of this difference to the weaker

starting position the Habsburg Empire had compared to their northern rival. The Habsburg rulers always faced a stronger resistance by their own nobility, found it harder to introduce institutions that would centralize their powers, and could therefore not take advantage of all their belongings as much as Brandenburg was able to bring them to the table.

A part of this failure becomes apparent as the Habsburg dynasty was never successful in uniting the Holy Roman Empire. Recent literature has reappraised the Holy Roman Empire in this light and saw the high fragmentation as economically advantageous. Some have highlighted the positive effects of interstate competition which was not limited to destruction through wars, but on the contrary productive, in terms of immigration, technology, not to forget institutional competition (Volckart, 1997, 2002; Wilson, 2016). Its structure circumvent wars, and the massive potential for war was only revealed when it failed altogether, such as in the Thirty Years War (Wilson, 2016). Wilson also argues that the Holy Roman Empire was indeed successful at being not-centralized. Neither any outside power, nor the Habsburg Empire, was able to reduce princes' freedom before Napoleon. In the end, the decrease in market integration (Wolf, 2009) might have come with an increase in innovative power (Jones, 2003; Ko et al., 2014).

An indicator for princes' resistance against further centralization and a stronger Habsburg government was also their dealing with uprisings. While 'Lutheran before Luther' (Cahill, 2014, p. 24) John Ball faced the united action of English nobility, Luther himself was hidden and supported by some princes. This eventually lead to a coalition against the Habsburg monarchy, the Schmalkaldic League, and the two single most bloody wars before 1900, and a permanent schism of the Roman Catholic church[6].

2. The Hohenzollern lands

2.1 Brandenburg

The Hohenzollern dynasty, originally from the South of the Holy Roman Empire, acquired Brandenburg in 1417, first only a small territory around Berlin. The uniform, empty, and boring nature of the lands, the poverty of the soils, and the low state of population have inspired poems,

[6]For example, (see Wilson, 2009, p. 41) for a discussion on the link between Imperial Law and the hope for a reunification of the churches after the Peace of Augsburg 1555

accounts, and even canonical German literature, most famously by Theodor Fontane (see Clark, 2007, for an overview). (Clark, 2007, p. 3) has questioned the stereotype of a totally infertile land, as some regions could indeed only be sown very seldom, and also infertile water-land, while other regions were intensively cultivated. Also, Brandenburg came with one of the seven electoral votes. What is often retold as a prestigious, but economically hopeless endeavor, became the core of one of the five European super powers in the 17th century. This process was mostly a long sequence of land accessions. Their integration however was a story of the aftermath of the Thirty Years War.

The later province Wernigerode was already connected to Brandenburg ever since 1268. This tiny, rugged, but populous and mineral rich area in the Harz region, back then the most important deposit for potassium salt, but also metals, added a domestic source for these raw materials. Its terrain as such was complementary to the plane Brandenburg, and therefore stayed an independent province over many centuries. For an analysis of the effect of geography on taxation, however we should bear in mind that this province, an outlier in sectoral structure, ruggedness, and also a rather small territory, would behave differently than others.

Table 1: *Development of Hohenzollern lands. The county of Wernigerode was part of Brandenburg ever since 1268. The year names the year full control over the province was gained.*

Year	Province(s)	HRE
1417	Electorate of Brandenburg and County of Wernigerode	Yes
1525	Eastern Prussia	No
1614	Counties of Mark-Kleve, Ravensberg	Yes
1648	Archbishoprich of Magdeburg, Abbey of Minden and Counties of Mansfeld and Halberstadt	Yes
1657	County of Lauenburg-Bütow	No
1659	Pomerania	No
1660	County of Draheim	No

After the Black Death, a first goal of the Hohenzollern was to repopulate the country, additionally facing the threat of outmigration towards the East. Still in 1450, almost 30% of farms in the *Mittelmark* where still left unpopulated, and hundreds of towns were left behind (Carsten, 1964). To contain this and its effect on tax revenues, Estates agreed that migrating peasants would be sent back to the region they came from. Starting in 1445, peasants needed to provide permits to

leave (Carsten, 1964). The original model proposes migration to independent city states as a main driver of urbanization, and therefore limits the tax capacity of territorial states. Imperial cities were a major destination for subjects willing to flee, so that the state of Brandenburg benefited from the absence of Imperial cities in its proximity. In addition, political fragmentation in the North East of the Holy Roman Empire was much lower than in its south west, so that this channel of urbanization is expected to be much weaker. Also, the role of agriculture for taxation diminishes later, compared to other states in the Holy Roman Empire. Preexisting urban centers founded by the Romans were non-existent. The results of the absence of competition with other states' were mixed. First, the absence of competition from imperial cities reduced the threat of emigrating subjects. Second, the positive effects of an increase in proto-industry and the role of trade could not be taken advantage of. When this was realized, towns and cities were founded in a planned fashion, by 'locatores' (see Brenner, 1976). This is especially true in Brandenburg. Ellenberg (1990) shows that the predominant town model in Brandenburg is the linear village, or street village. This points at a rather late settlement, compared to village models in the rest of today's Germany. Prioritizing the rural areas, cities were forbidden to shelter fleeing peasants, some cities resisting these demands for years, e.g. Anklam in 1458, or Köpenick in 1483, but eventually gave up resistance (Carsten, 1964).

A state with strong Estate representation was also never developed in Brandenburg. High nobility never existed, the share of lands that belonged to the Elector was higher than anywhere in Europe. The view of Carsten (1954) who argued that the Hohenzollern were 'primus inter pares' between lower nobles in Brandenburg before the 17th century has provoked a strand of literature showing the opposite (Baumgart, 1969). One should not confuse the idea of a central administration with administrative modernity. As pointed out by Willoweit (1982), Brandenburg was certainly not a forerunner in constitutional development that eventually lead to today's democratic constitutions. He argues that only with the introduction of a privy counselor (*Geheimrat*) in 1603 Brandenburg caught up to constitutional standards established elsewhere in Europe, mostly Austria and also smaller German states. Already then, however small beginnings of the central administration rivaling estates interest is more successful then elsewhere. The estates were not called for decades already in the 1500s. They had no right to gather on their own demand, and they would also

never be called after 1653 except to applaud at official events. (Baumgart, 1969)

Scheuner (1965), among others, has argued that the expansion of Brandenburg-Prussia to countries both inside and outside the Empire, being ethnically diverse, lacking a uniform cultural background, language, or even religious confession, called for a strong state to substitute other ties. This is in line with economic literature finding that the provision of public goods becomes more costly with more ethnic heterogeneity (Alesina et al., 1999). These divisions could also affect subgroups to lobby for more autonomy (Alesina and Spolaore, 1997; Bolton and Roland, 1997), which needed to be countered in the attempt to centralize the state.

The region that eventually lent its name to the whole of the Hohenzollern's belongings, Eastern Prussia, was gained in 1525, when it was secularized, expropriating the German order. Like Brandenburg, this province's geography is plane and uniform. This already had consequences for the defense structures built, including Europe's largest Medieval castle, Malbork castle. Rugged terrain elsewhere in Europe provided castle builders with both elevated grounds to built upon and rocks to use as building material. The German order had to turn to bricks, and the plane lands allowed a single castle design to be copied across the country without having to adjust the plan to the building ground. Featuring important Medieval trade hubs with a legacy in the Hanseatic League, such as Danzig and Königsberg, Eastern Prussia included cities with a strong urban elite. This was especially so after the Thirty Years War, in which both cities were able to increase their trade, also due to the war involvement of other sea harbors, such as Rostock or Bremen (Zorn, 1971, p. 533).

The 17th century repeatedly brought the Hohenzollern lands at the verge of collapse, but eventually came with huge additions to its land. This started in 1614, when a quarrel over inheritance lead to the acquisition of the Counties Mark-Kleve and Ravensberg. These territories which were not geographically connected to the core regions not only resulted in the country spanning from the Dutch border to Prussia, but also increased its heterogeneity immensely. Especially, these very urban and commercialized regions of Mark and Kleve, the core of today's Ruhr area and densely populated also back then, promised both a high potential for tax revenue, but also a high resistance against it.

The case of Pomerania was more complicated, and full of ambitions and drawbacks from Hohenzollern perspective. In 1648, Pomerania was split into one Swedish and one Hohenzollern part. During the Northern War, the Electorate gained control over the whole Pomerania until 1659 (Clark, 2007, p. 50), but would then loose it again due to French and Habsburg intervention, before regaining it after the Brandenburg-Swedish war.

From the Peace of Westphalia, the Hohenzollern received significant regions due to secularization, the Archbishopric of Magdeburg (which included the County of Mansfeld), and Minden Abbey. The Bishopric of Halberstadt, again extending the Electorate into the mineral-rich Harz region. The last Brandenburg-Prussian extension in before the seventeenth century was the one of Draheim in 1660.

Population estimates for the time are hard to find, especially due to the Thirty Years War itself. Pfister (2011) argues that the urbanization rate between 1600 and 1700 is actually decreasing, since the number of city inhabitants recovers slower than those of the whole population. Following the data by Franz (1979), war casualties in Kleve-Mark would be relatively low (under 20% of population), while it was 40–50% in Brandenburg, and over 50% in Pomerania. Around the Northern War, following the estimates by Fay (1917), Brandenburg would represent around a third of Hohenzollern's subjects , followed by Prussia (30%), Kleve-Mark (around 15%), Minden and Ravensberg jointly 7%, and Halberstadt 5%.

III. Empirical Analysis and Results

1. Brandenburg and Its Competitors in the Long Run

To conduct a long run comparison between Brandenburg and its closest competitors, the Electorate of Saxony and of course the Habsburg monarchy, I use the data set on the Holy Roman Empire by Huning and Wahl (2017) which allows to compare the geography each of these regions contained within their respective borders 1250–1789. Since large parts of the Hohenzollern's estates were never part of the Holy Roman Empire, I extended the data set by these territories to capture the whole of Brandenburg-Prussia.

Table 2: *Development of observability and basic geography of Brandenburg-Prussia and its closest competitors 1477–1789*

Year	State	Indexed Observability	Caloric Suitability	Area in km^2
1477	Brandenburg	1.000	2056	32031
	Habsburg	0.200	1714	37852
	Saxony	0.451	1802	19894
1555	Brandenburg-Prussia	0.861	1980	22970
	Habsburg	0.269	1619	137965
	Saxony	0.365	1716	16530
1648	Brandenburg-Prussia	0.726	1876	99866
	Habsburg	0.192	1458	193456
	Saxony	0.425	1810	24870
1789	Brandenburg-Prussia	0.670	1835	164233
	Habsburg	0.169	1393	181861
	Saxony	0.469	1862	37354

Note: The caloric observability was normalized by dividing the caloric noise of Brandenburg-Prussia in 1477 by the caloric noise (see Huning and Wahl, 2017)). Caloric suitability denotes the average caloric yield using data was taken from (Galor and Özaka, 2016; Galor and Özak, 2015) and generated using the maps of (Huning and Wahl, 2017). For 1378–1477, fruits that arrived in Europe during the Columbian exchange were excluded.The numbers for Saxony exclude Poland, as this was never a part of the Electorate.

The descriptive statistics of Brandenburg(-Prussia) and its closest competitors provided in table 2 support a very long run perspective on geography's role for these states' development.

Consider the caloric suitability, and the area controlled by the dynasties in 1477, 1555, 1648, and 1789. Any changes are due to composition of the territories, except that the suitability data in 1477 excludes sources of nutrition that were only available in Europe after Columbus. Taking control over parts of today's Austria in 1278, the Habsburg dynasty leads in terms of area controlled. Given the increasing returns to scale (Bean, 1973), amplified by the Military Revolution (Tilly, 1993; Gennaioli and Voth, 2015), the dominance of the Habsburg Empire is in this light non-surprising. We also see that the expansion of the Hohenzollern is a question of the time after 1555, while the Habsburg lands increased in size much earlier, especially due to increasing control over Austrian lands. Brandenburg' area is decreased in 1555 because of its partition 1535–1571.

Two findings can be drawn from comparing the caloric suitability of the three lands. First, the Habsburg lands are constantly expanding into regions that reduce its average suitability. In the light of the stories of the bad agricultural conditions in Brandenburg, it is surprising that the Hohenzollern lands have indeed the highest yields, and are also able to keep a high state. Following the literature (Nunn and Qian, 2011; Galor and Özaka, 2016; Galor and Özak, 2015),

it is assumed that fruits and grains from North America can be grown in Europe where this is beneficial right after 1500. This reveals that the Columbian exchange, mostly the potato, could have had an impact on the development of the Hohenzollern's land. However, Frederick II. and his 1742 acquisition of Silesia, with a suitability only slightly below Brandenburg's previous average, seem to have a more traceable impact the legend about the King himself introducing the potato to the peasants of his country with his own hands (see Clark, 2007)).

Regarding our key measure, the observability, when one indexes everything using Brandenburg's value in 1477, one sees a steady decrease in the observability of the Hohenzollern's land. From 1535 to 1571, a part of Brandenburg was an independent princedom, Brandenburg-Küstrin, which controlled the Eastern territories. The decreasing number in average observability indicates that the most observable Brandenburgian lands have been to in the Odra region. After reunification and expansion via Kleve, Minden, Ravensberg, and secularized Magdeburg, the Hohenzollern 'controlled' de jure a much larger territory in 1648, which was on the downside way complicated to tax. However, once comparing their number of $72,6\%$ of their initial observabiliy index of 1477 with Saxony or even the Habsburg lands, their observability is outstandingly high. For example, the Saxonian Electors already started with a much lower observability in their very rugged core lands around Dresden and Leipzig, but were able to grow into regions that were better taxable until 1789. The regions around the Electorate of Saxony were very politically fragmented. Speaking with Huning and Wahl (2017), this could indicate that these areas were also hard to tax. Concerning Austria, controlling larger the Sterymark and Tirol came with an increase in observability, but the additions after 1555 reduce average observability. Any increase in area from 1555 onward is associated with a decrease in observability, so that taxation of the new belongings, considering the resistance of the old elites, was also occupied by simple geographic constraints. We can argue that if technology in administrative means, even if it was common, must have yielded less success than in terrain that was much easier to assess. It is therefore reasonable to assume that the reforms that did take place all over Europe, including Austria and Brandenburg-Prussia, found less grip in the Emperor's land than in the Brandenburg plains.

2. The Development of Military Contributions after the Thirty Years War

To trace the development of military contributions after the Thirty Years war, I digitized data on the Hohenzollern's provinces from 1650–1681 from Wolters (1915). These data are based upon the official military statistics that provide itemized data on military spending of the time, which Wolters aggregates to one number per province per year. The author himself coins this endeavor a 'trial', however the data set seems to be relatively consistent in longitudinal direction, across provinces, but also with the more detailed data provided in other tables in the same book.

In the first year reported, 1650, only five provinces pay any contributions. These are of course the Mark of Brandenburg, which pays 150,000 Taler, followed by Halberstadt (50,000), Ravensberg and Mark-Kleve (each 40,000), and Minden (36,000). While it may not be surprising that Brandenburg has to pay the bulk of the military spending, the other numbers, especially their proximity in levels, is stunning. The first reflex upon consulting the map, that territories so different in size would contribute so similar numbers, is supported by closer inspection of these provinces. How can an economically advanced Kleve, a core of today's Ruhr Area, almost untouched by the Thirty Years War, contribute the same amount as the much smaller Minden, which is so less urbanized and also much smaller in size? The reader is tempted to see these contributions as arbitrary, or symbolic, as the background on economic diversity in these regions would lead him to expect a different picture. The impression of arbitrary contributions is further strengthened looking at the next two years, in which Kleve-Mark first raises its contributions by the factor of three, falling back to only 30,000 in 1652. Pomerania is reported as contributor in 1653, starting at 50,000 Taler, Eastern Prussia the year after with 6,000. This number can be explained by the fact that Eastern Prussia was not under Hohenzollern control for the complete year.

The beginning of the Little Northern War, more precise the conclusion of the Treaty of Rinsk im 1655, induces a rise in the sum of contributions from 335,465 to 1,440,802 Taler. In this treaty, concluded in November 1655, the Eastern Prussian nobles called upon the Brandenburg Elector to defend them against the Swedish invasion. The bulk of this increase was carried by Eastern Prussia itself, which due to its contributions of 600,000 Taler (compared to 360,000 of the Mark of Brandenburg) became the leading contributor. What is intriguing is that Kleve and Mark, on the

other side of the Electorate and not endangered by Swedes, adjusts its contributions from 50,000 to 250,000. The war time contributions seem to reflect better the expected ability of provinces to contribute given by their economic credentials. However, when regarding the relative increase between the last year in peace and the year after, its questionable how Ravensberg more than doubles its numbers while Halberstadt remains at the same level. In 1660, Draheim (2,500 Taler) and Lauenburg-Bütow (4,000) start contibuting.

Are the increases of the first war years sustainable? Contributions dropped from a peak of over 2 Million in 1658, to around 850,000, and would never down to prewar levels again, also when excluding the new provinces. Does the trend of a perceived convergence of economic potential and contributions persist? Already during the war, Eastern Prussia reduces its contributions to slightly less than a 100,000 in 1663, which is less than Pomerania in the same year. Indeed, both provinces faced a large destruction during the time, however Eastern Prussia being much more urban. Eastern Prussia's low contributions can be apologized by the large contributions it paid the years before but can also be interpreted as a successful attempt reduce the Hohenzollern's grip once the danger is over. Many provinces after the war go back to their prewar contributions, some to the exact same sum, as Minden and Ravensberg. Eastern Prussia would contribute as much as 120,000 in 1667, but increase this share to 280,000 in 1672 before reaching a 240,000 equilibrium that it would keep also through the Swedish-Brandenburg War. Pomerania would continue to pay around 100,000, which indeed reflects also their relative economic potential. The small provinces Draheim (2,500 Taler) and Lauenburg-Bütow (4,000 Taler) would continue to pay the exact same contributions until 1679, the end of the Swedish-Brandenburg War.

During the Swedish-Brandenburg War (1674–1679), although never as costly as the Little Northern War (peak of contributions 1,717,231 Taler in 1678), the bulk of the contributions is paid by the Mark of Brandenburg. As it is also the target of the Swedish invasion, this is not surprising. Looking closer at the other provinces, there seems to be indeed a higher contributions of provinces that are less affected. Eastern Prussia in 1672 contributes as much as 420,000, almost as much as the Mark of Brandenburg (549,125 Taler). Pomerania also contributes almost 200,000, and the contributions of Magdeburg sum up to 120,000. Mark and Kleve peak at 226,000 in 1678. At the end of the war, the numbers appear much more to reflect economic potential, as they show also a

large heterogeneity. This pattern would also not disappear after the war, as contributions oscillate around 200,000 for Eastern Prussia, stay at 144,000 for Pomerania, increase to a stable 200,000 for Magdeburg, 30,000 for Mansfeld (which started contributing as late as 1680), around 90,000 for Halberstadt, 10,000 for Wernigerode, around 60,000 for Minden, 44,088 for Ravensberg, 120,000 for Kleve and Mark, and 454509 for the Mark Brandenburg in 1697.

The assessment of 'symbolic' contributions of the first years in sample seems to have been replaced by numbers that do reflect some variance in provinces' ability to contribute. To study whether this change in pattern can be linked to geographic fundamentals, in the next step I will connect these data to the theory of observable agricultural output, and will also use data on city population to account for heterogeneity in the urban economy.

3. The Role of Caloric Observability for Contributions

To insure coherence with the data set from Huning and Wahl (2017), I digitized the shape of the Prussian provinces from the same source, Wolff (1877), and employ the map of 1648 for over the whole sample period. This is the consequence of trading off the changes due to redrawing of the maps during the times, and fitting and adjusting maps from other sources to create a historically 'correct' map introducing new sources of inaccuracy. Most importantly, we would expect the province of Pomerania to be most viable to this limitations, as here lies the core of the fights with the Swedish. When interpreting the results, keep in mind these untraceable and continuous changes to the geography and its initial division and repeated unification.

To run my regressions, I exclude all provinces from the data set for all years in which Berlin did not have control over them. Should there be debates[7] on the exact timing, I referred to Köbler (1988) for reference. Therefore, the data set allows me in parts to abstract from regional denominations, and compare territories that could be controlled by a central government. The process of actually centralizing is at the core at this paper, so that the success of realizing these potentials can be illuminated.

In order to understand the role of the aftermath of the Thirty Years War for the development of a Prussian central state, I will first provide some description of the development of the absolute

[7] See also the discussion in Huning and Wahl (2017).

Table 3: *Impact of caloric observability on contributions*

	Dependent Variable: Contributions per Square Kilometer										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Linear Time Trend	1.018**	1.018**	1.019**	1.019**	1.019**	1.018**	1.018**	1.019**	1.018**	1.018**	1.018**
	(0.00674)	(0.00659)	(0.00658)	(0.00660)	(0.00661)	(0.00657)	(0.00654)	(0.00664)	(0.00659)	(0.00656)	(0.00659)
Caloric Observability	1.003***	1.002**	1.001	1.009*	1.002***	1.003**	1.003**	1.002*	1.004***	1.003**	1.002**
	(0.000731)	(0.000705)	(0.000992)	(0.00353)	(0.000364)	(0.000972)	(0.000814)	(0.000858)	(0.00121)	(0.00116)	(0.000804)
Caloric Suitability	1.000	1.001	1.002	1.000	1.000	1.001	1.000	1.002	1.007	1.003	1.001
	(0.00138)	(0.00194)	(0.00182)	(0.00124)	(0.000856)	(0.00182)	(0.00232)	(0.00221)	(0.00350)	(0.00186)	(0.00148)
Longitude	1.000**	1.000*	1.000	1.000	1.000	1.000**	1.000	1.000*	1.000***	1.000***	1.000*
	(0.00000106)	(0.00000150)	(0.00000180)	(0.00000143)	(0.000000921)	(0.00000133)	(0.00000191)	(0.00000160)	(0.00000104)	(0.00000178)	(0.00000136)
Elevation	0.989**	0.992	0.981***	0.961***	0.977***	0.990*	0.987*	0.992	0.989***	0.992*	0.991*
	(0.00355)	(0.00433)	(0.00554)	(0.00979)	(0.00435)	(0.00519)	(0.00661)	(0.00489)	(0.00297)	(0.00394)	(0.00381)
Urban Population 1650		0.986	0.982*	0.998	0.991*	0.997	0.989	0.987	0.980*	0.982**	0.987
		(0.00925)	(0.00858)	(0.00916)	(0.00449)	(0.0168)	(0.00814)	(0.00893)	(0.00906)	(0.00671)	(0.00763)
Ruggedness			1.060*	1.076**	1.059**						
			(0.0252)	(0.0289)	(0.0200)						
Halberstadt FE				0.0196*							
				(0.0343)							
Wernigerode FE					3.093***						
					(0.395)						
Brandenburg FE						0.398					
						(0.399)					
Distance to Oceans							1.005				
							(0.00472)				
Distance to Trade Roads								0.998			
								(0.00309)			
Distance to Berlin									1.000		
									(0.00000410)		
Distance to Pottasium Salt										1.004	
										(0.00432)	
Distance to Hanseatic Town											0.994
											(0.0315)
N	501	501	501	501	501	501	501	501	501	501	501
Pseudo R^2	0.451	0.476	0.491	0.533	0.594	0.483	0.486	0.485	0.520	0.483	0.477
AIC	7307.7	6975.2	6785.8	6219.4	5414.6	6881.4	6849.9	6861.0	6395.7	6892.4	6968.6

Note: Exponentiated coefficients; Robust standard errors clustered by province in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

contributions, before assessing the effect of obervability econometrically. Over the whole period, the main contributor after Brandenburg 150,000 Taler was the secularized Archbishopric of Halberstadt (50,000) closely followed by Minden, Ravensberg, and Kleve (around 40,000 each), all the other provinces not contributing. A central task of a centralized government is to asses the amount each province is able to contribute. This should result in more heterogeneity in payments, as in any effective contribution system, one would not expect rich and urban Kleve and the rural and minor Ravensberg to pay about the same contributions.

There are overall 501 observations of contributions in the sample I constructed. Wolters (1915) does not distinguish between provinces that were part of Brandenburg-Prussia and those that did not. In order to exclude all observations of provinces that were not part of the country, I exclude Eastern Prussia until 1655, Lauenburg-Bütow until 1658, and Draheim until 1665.

The twelve provinces in my sample vary considerably in size. Their existence was not an outcome of administrative arrangements (which might lead to equally sized territorial units) but a historical process in which tiny provinces, such as Wernigerode (see fig. 1) stands on the same level as Brandenburg. In order to account for this initial difference, we can not compare the absolute level of contributions. Given the difficulty to find valid estimations for the rural populations, the analysis is limited to the contributions per area as the most reasonable indicator. In order to justify this, we need to bear in mind that the actual quality of the soil has to be accounted for, and also control for some degree of urbanization. The histogram of the contributions per square kilometer (fig. A.1 of the appendix) first indicates that there is no normal distribution, especially due to the many observations with zero or very small contributions. This is an important part of the proposed development to a state in which provinces' contributions are related to their economic credentials. The histogram does not propose the existence of distinct processes, one that decides whether states pay at all and then a second process that decides on the level, there doesn't seem to be such a hurdle. I propose that the overall distribution of the data can be caught at best by a Poisson estimator. The small number of observations does not allow a legit panel exercise, so that I pool all data and run a single regression with robust standard errors clustered at the province level.

Consider table 3. In column (1), we learn that there exists a significant linear time trend of

rising contributions. Caloric observability is significant, and its estimate propounds a positive and economically significant relationship between how well the geography allowed the central government to assess agricultural output and the contributions it received. The caloric suitability of a province has a zero and insignificant effect. This is in line with the theoretical argument of Mayshar et al. (2017). To control for the Eastward settlement direction of Central Europe (and also the Roman legacy in the West of the territory) I control for the longitude. To control for the idea that proximity to the Baltic Sea and the Atlantic could have had ample effects on the regions, I also control for elevation. In column (2) I include the sum of all cities' population within the region. I use the data set from the Centre for Global Economic History[8] and hold the population constant at its 1650 level. Following Pfister (2011), I assume that the absolute level of city population is rather constant, while the rural population increases in absolute number after the Thirty Years War. The estimate from column (2) suggests that city population is not statistically significant by itself, at least not across the whole sample.

Once I include ruggedness as an instrument for the opportunity costs of agriculture, especially mining in the Harz regions and proto-industry in Mark-Kleve, in column (3), city population is indeed significant. Ruggedness itself has a positive effect. The downside of the ruggedness measure is that it is highly correlated with our main explanatory, caloric observability. Ruggedness is, among others, a reason why crop yields should vary. Also by construction, using the same GIS procedures of generating the variable, ruggedness and caloric observability are related. The correlation across the sample is 0.81. However, they are conceptually two different things, so that a closer investigation in the driver of this behavior is necessary. Among the top contributors, especially in the beginning of our sample, is Halberstadt, which is also very rugged. Controlling for this particularity in column (4) attributes a highly significant, and even stronger effect to caloric observability. When controlling for the other Harz region in our sample, Wernigerode, in column (5), the significance of the caloric observability prevails, but its effect is back at the estimate from column (2). However Wernigerode is as rugged as Halberstadt, in contrast to Halberstadt it is not a top contributor. The exercise from columns (4) and (5) indicates that the correlation between ruggedness and caloric observability is highest in these two regions, and that

[8]The data can be downloaded here:
http://www.cgeh.nl/urbanisation-hub-clio-infra-database-urban-settlement-sizes-1500-2000

ruggedness and observability have discrete explanatory power controlling for the particularities of any of these two regions. Another region that is naturally interesting to look at is Brandenburg, the core of the state. The statistically insignificant estimate suggests that Brandenburg is indeed not different to the others, at least not in the time we are looking at.

Finally, to control for other geographic variables which could potentially alter the results, I control for distance to oceans, to Medieval trade routes (using the data from Huning and Wahl (2017)), to Berlin, and also Potassium salt mines. All these variables are robust to the area of the province under investigation, as distance is calculated as the distance of 1,000 random points within the territory to the closest ocean, road, or Berlin. The distance to the oceans aims at capturing ease of trade access which is not already captured by the elevation variable. Distance to trade roads is relevant for the inland provinces and their legacy of being connected to the European trade network during the Middle Ages. Distance to Berlin in column (9) could measure an alternative explanation for observing agricultural output other than the one proposed in this paper (see e.g. Olsson and Hansson, 2011)). Potassium Salt in column (10) could be an exogenous instrument for the existence of urban trade cities which resisted centralization due to their established representatives (see Wahl, 2017). I included the distance to the closest Hanseatic town which were digitized digitized from Andree (1886). The estimates in column (11) indicate that the Hanseatic tradition of proposedly more independent cities did not have a significant effect on the contributions, at least not as far as I can show it with this limited sample.

The above cross sectional analysis points at some positive and significant relationship between how well a province's agricultural production can be observed and its contribution to the central government. However, the historical narrative suggests that during the period 1650–1693, the administrative system of Brandenburg-Prussia underwent substantial changes. We are interested in whether small or symbolic contributions at the beginning that are presumably unrelated to economic credentials increasingly relate to the potential of provinces to collect taxes. Two sources of income can be distinguished: City population and rural population.

Consider table 4. I interacted both the caloric observability and the urban population with year dummies. All other controls were included as in the regression (4) from table 3, which I trust most as it features ruggedness and accounts for the particularity of small but mineral rich Halberstadt.

In this table, I present the results grouped by four year periods and report only the first and last of these periods. The regression yields no significant linear time trend, but the passage of time is explained by the interaction between time and observability and time and urban population. Consider the estimates for caloric observability. The estimate for 1650–53 is larger, and regarding the standard deviation also in a statistical significant way. However, at the beginning of our period, the contributions do not depended on the observability of the soil in a statistical significant way. At the end of the period, this is indeed the case. Now focus on the estimates for urban population. It is significant at the beginning and the end our our period. The number below one indicates that city population indeed resisted and/or complicated contributions, so that their net effect was negative. However, the amplitude of the effect is decreasing. All other controls show similar results as in column (4) of table 2.

The fact that the significance of observability increases with the passage of time demands some explanation. Huning and Wahl (2017) argue that for the long run, due to the advances in military technology, urbanization, and other historic developments, the relevance of agriculture on taxation decreases. The historical narrative suggests that Brandenburg-Prussia was a late-comer relative to the other states in the Holy Roman Empire, given its low competition from other states and also Imperial cities. When the Elector started to collect taxes from the provinces that were reluctant before, there were only two options: Taxing the rural population (facing resistance from the nobility) or taxing the city population (facing the resistance of their representatives). Taxing agricultural output is easier in areas which are well observable. The significant estimate suggests that the central government took advantage of their geographic property. Those provinces were taxed higher than others, as these provinces could not hide their real output as well as others. Presumably, the landed nobility was weaker in defending their rents in these areas. Combining the long-run and short-run perspective, we would expect the effect of rising significance to disappear, at latest when the urbanization of the 18^{th} and the Industrial Revolution shift the balance between rural and urban production. The urban population, rather stagnant in absolute numbers during this time (Pfister, 2011), was presumably better in defending their privileges in 1650 as they were in 1697. However, the effect of an additional citizen for the contributions should become positive in the long run. The reforms under Frederick William, following the Swedish role model,

Table 4: *The changing role of urban population and caloric observability 1650–1697*

	Dependent Variable: Contributions per Square Kilometer
Linear Time Trend	1.003
	(0.00977)
Caloric Observability 1650–53	1.000
	(0.00211)
...	
Caloric Observability 1694–97	1.002***
	(0.000356)
Urban Population 1650–53	0.967**
	(0.0118)
...	
Urban Population 1694–97	0.987***
	(0.0104)
Caloric Suitability	1.000
	(0.000861)
Longitude	1.000*
	(0.000000966)
Elevation	0.979***
	(0.00459)
Ruggedness	1.058**
	(0.0206)
Halberstadt FE	3.293***
	(0.496)
N	501
Pseudo R^2	0.650
AIC	4673.4

Note: Exponentiated coefficients; Robust standard errors clustered by province in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

were aimed at breaking the resistance of a landed nobility, and not at cities. Reforms raising the contributions from cities were mostly left to Frederick William's successors. For example the indirect tax collected at all city walls, the *Accise*, which followed a French blueprint, was only introduced by Frederick William I., King of Prussia (1688-1740).

Concluding the empirical exercise, these data hint at a development of Brandenburg-Prussia's provincial contribution to be increasingly linked to actual economic potential. Therefore, hypothesis 4 is supported. For the case of cities, these data support the idea that they were more resistant. For the rural areas, a higher observability is increasingly linked to higher contributions, which supports refhyp:positive. This hints at a decrease in the rents of landed nobility. This in turn, as suggested in the theoretical section, might have had multiple implications for their attachment to the state. These results might indicate that the Swedish blueprint of concentrating the reforms on the rural population and rural elites were rather successful. The overall increasing effect of caloric observability adds a short run twist to the long run mechanism outlined in Huning and Wahl (2017), and by doing so also contributes to a more complex understanding of the role for geography on taxation.

IV. How Brandenburg-Prussia Increased Taxation and Centralized its State

To inspect the mechanism, the following historical outline provides further evidence to interpret the results.

The reforms and Brandenburg-Prussia have to be viewed in the context of other European states, especially France, Denmark, Sweden, but also other German states (including of course Austria), that increasingly create absolutist governments. What distinguishes the experience in this Electorate is however the rigidity of these changes (Oestreich, 1971, p. 84).

Public finance in Brandenburg until the Thirty Years War was organized collaboratively between Elector and estates. In the 16^{th} century, the estates had agreed to take over the Elector's debt, themselves founding a state bank issuing bonds to finance these debt (Baumgart, 1969, p. 532). As collateral, Estates supervised the collection of direct and indirect taxes of that time, mostly

Hufsteuer (hidage, a tax on horses and lifestock) and *Giebelsteuer* (a land tax) (Baumgart, 1969, p. 531). At the end of the war, not only was the bank bankrupt (Baumgart, 1969, p. 534), but also the changing scope and organizational necessities of wars in general, and precisely the geographic span of the Elector's land and the idea of centralizing authority, initiated a process of reforms that lead to a sharp decrease in the role of the old elites. These reforms, under Elector Frederick William (1620–1688), had three main consequences. First, the recruiting system of the Thirty Years War would be replaced by a standing army. During the Thirty Years War, states contracted the organization of recruitment to officers, who would independently muster, pay, and train mercenaries. This lead to huge discrepancies between the number of soldiers 'ordered' and how much would be 'delivered' on the battlefield (Fay, 1917; Frost, 2000). Second, the finance of the standing army was centralized, depriving existing estates of their powers. Third, central commissions and administration would organize the collection of these contributions, facing resistance from existing elites, to reduce (or overcome) the multi-layer principal-agent problem of tax collection.

A central figure in initiating these reforms was Kurt Bertram von Pfuel (Oestreich, 1971). During the Thirty Years War, von Pfuel had spent several years in the administration of Sweden, where he witnessed the system of military organization, but also taxation and administration. The main aspects of his reform were a standing army, and a tax system that would collect taxation from all sources, a strong central administration, as well as the collection of statistics, but also an officers corps that would consist mostly of nobility, so that this group would be attached to the central state (Oestreich, 1971, p. 36). When von Pfuel passed away in 1649, these reforms have not been implemented yet, but pointed the way into the direction they would steer in.

An important precondition for centralization were constitutional changes in the Holy Roman Empire. After holding the legal role of the nobility relatively constant over centuries (Wilson, 2016), this changed with an Imperial edict in 1654. Whether this law would serve as the 'Magna Carta of absolutism' (Clark, 2007, p. 58) not only depends on its legal content, namely all subjects had to assist princes in their war efforts, but also princes' ability to enforce their claims against resistance. The local estates defended their rents and privileges. Given that all of these three territories have their own outer border, Estates could also put in doubt the effect of a common provision of defense

(Fay (1917), see fig. 1), and were probably right in assuming that the central provision of the public good security could be followed by the other public goods, questioning their privileges, and reducing their rents. Especially for Kleve, this very dense territory with a relatively small border, elites were not only rational for their own sake, but also for their subjects refusing to subsidize other provinces, pointing at economic literature on the size of nations (Alesina and Spolaore, 1997; Bolton and Roland, 1997). This however is not very plausible in the light of the external threads to Kleve. It had been occupied by the Dutch during the Thirty Years War, and it would be occupied and looted by the French in 1672 (Clark, 2007). Schmoller (1877) goes as far as stating that Estates were more willing to accept directions from Amsterdam, Vienna, or Warsaw, than from Berlin. In this light, it seems plausible that Fay (1917) was right when pointing at a principal-agent problem, in which the old elites are trying to save their privileges, risking a lower level of protection. To provide an exemplary quote, Fay (1917, p. 765) describes the situation after 1648 in Brandenburg, East Prussia, and Kleve:

> *"In each of these territories the real political power was in the hands not of the ruler, but of the local Estates. These were composed of the privileged feudal nobility and the selfish burgher aristocracy. In each territory theses Estates thought only of their own local interest and class privileges. They refused to raise taxes except such as would spent for local purposes under their own local control. They refused to raise troops for any purpose except local defense. They refused to recognize as officials of the Elector all persons who did not belong to the native-born of the territory."*

In order to create a standing army, and allow planning over years of war and peace without constant renegotiation with the estates, the role of the six year plan of 1653 was a break through (Schmoller, 1877). In return, Estates were given the right to introduce serfdom in regions it was formerly not allowed (Schmoller, 1877). On the one hand, due to stronger limitations on the mobility of peasants, reduced the Elector's room to foster urbanization and proto-industry, which was certainly his aim. On the other, as Schmoller correctly assesses, long-term financial pledges for a standing army also allows to institutionalize administration.

A central mechanism of these institutionalization was the creation of central institutions in competition with existing ones, eventually replacing them. These were mainly the nomination

of commissioners (*Kommissare*) by the Elector. Following the above quote by Fay, constituting commisioner's foreign to the provinces faced strong resistance, but eventually succeeded. As outlined by Otto Hintze in his 1910 compendium on state and constitution[9], they fulfilled the Elector's expectations of reducing the old elites' role,

> *"The commissioner's authorities have no roots in old estates' constitutions nor common law; they face the old order without understanding, but with determined hostility: they are the main instruments of shattering the old corporate state and the creation of a new absolutist military state."*

The most important of these officials was the General War Commissioner (*Generalkriegskommisar*), who was introduced in 1655, following a French blueprint (Clark, 2007, p. 43).

It was during the Little Northern War (1655-60) that these reforms were more aggressively pursued. Following the slogan *"Not kennt kein Gebot"* (necessity knows no law)[10] estates were forced to agree on contributing to the defense of Brandenburg, which they heavily resisted, especially East Prussia, telling him to 'seek refuge in good'[11] if the current defense would not be suffice. Clark (2007) points at the parallels with England, and the Country Whigs advocating for militia under the rule of local nobility. But unlike in England, the East Prussian nobility was forced to change their minds. Right when the Northern War came to an end, the Elector ordered 2,000 soldiers into Königsberg, arresting the leader, Hieronymus Roth, a representative of urban corporate rights (Clark, 2007, p. 59f.). It was also the Northern War when the General War Commissioner extended its scope from supervising military expenditure to trade policy, and even manufacturing policy (Neugebauer, 1981).

After the Northern War, the standing army was never revoked, and Estates' formal right to approve the budget became a formality (Baumgart, 1969, p. 524). Glorifying Frederick William, German nationalist historians have regarded this as a visionary move. Questioning this, Fay (1917) points at the fear of a resumption of war in combination with opportunistic behavior that led this behavior. < Some historians have pointed out the biography of Frederick William as an explanation for his actions. Especially, the years from 1634–1638 which Frederick William spent in the Netherlands

[9] Quoted from Hintze and Oestreich (1970, p. 245), own translation.
[10] Cited after Fay (1917, p. 770)
[11] quoted after Clark (2007, p. 56)

have been argued to be the origin of the reforms he would pursue. As outlined by (Tallett, 1992, p. 209f.) the Dutch system, with outstanding provincial independence that each had representative assemblies on the contrary was able to create high revenues due to the legitimacy such a relative inclusive and democratic system establishes. On the contrary, under Frederick William such local authorities lost power which Clark (2007, p. 43) traces to a French model. During the times when parliaments, however yet excluding the majority of the citizens, gained ground in Britain, it was on retreat in Prussia, when existing local assemblies of the nobility (*Landtage*) were actually abolished (Clark, 2007) due to an increasing centralization.

An important stepping stone on this way was also to reduce nobility's sovereignity within the military. The Electorate's new war rules from 1656 ('Kurfürstlich großbrandenburgische Kriegsrecht und Artikelsbrief') included the abolition of judicative elements outside of the Elector's reach, but also allowed his administration a tighter grip on the mustering of the troops and promotions (Oestreich, 1971, p. 81). After having ensured that the military, given the diminishing ability of the nobility to extract rents from agricultural output, this second step increased their dependence on the Elector himself.

Koyama (2010) has argued that expulsion of minorities is not a parallel process of a more inclusive government with better representation. To the opposite, he shows that more parliamentarian states can be more oppressive. Expulsion is, so his argument goes, an indicator for a lack of state capacity. In 1671, Frederic William lifted the ban against Jewish immigration to Brandenburg which was about a century old, a move followed by his other provinces (Oestreich, 1971, p. 92). This did not mean that all discrimination stopped, e.g. Jews entering the Berlin gates would still be subject to pig tax (Nirenberg, 2013), but the lift of the ban itself speaks for an increase in the Elector's central power.

The success of centralization however was not completed under Frederick William. Kleve maintained own diplomatic relations in The Hague until 1660 (Clark, 2007, p. 55), and would also its own estate meetings (*Landtage*) until the 18^{th} century (Neugebauer, 1981, p. 547). The process of centralization and decrease of old Estates' power was also not linear. Frederick William tried to exclude the estates from all sovereignty over public finances in 1687, but passed away while these efforts were still going on, followed by an episode of slightly more power over revenues for

credits to its successor Frederick III., who would eventually become Frederick I., King in Prussia (Baumgart, 1969, p. 532).

The move of of nobility into position of public offices and the military had long-run consequences, also for the German Empire. Demeter (1962) provides data for the heritage of students of German officer candidate schools. In 1860, 65% of the students were coming from the nobility. This was decreasing due to demographics and the increasing size of the military as a whole. However, in the eleven years before the First World War, 49 % of the students were still of noble descent, and the career of an officer was also rather hereditary—33 % of all students were sons of military officers. On first sight, this is a sign of a strong nobility with political influence. On the other, it speaks for the old elites' acceptance of the central government, and it is a sign of adaption to their new role. If Estates were not able to extract rents from their lands, and given that the German nobility was also a relative looser of the Industrial Revolution (Wehler, 1987; Lehmann, 2010), where else than in public institutions, where their social capital has not been devalued, would one expect the nobility? The key contribution of this paper is to root the key argument by Craig (1955), that the military had negative effects for the development of the German state and that these emerged already shortly after the Thirty Years War, to geography—the soil of Brandenburg, in interaction with historical circumstances, shaped some important part of German and European history.

V. Conclusion

This paper investigated further the effect of geography for effective taxation. Based upon the theoretical model by Mayshar et al. (2017) and in contrast to the very long-run approach taken by Huning and Wahl (2017), this paper zoomed in to a relatively short but eventful period after the Thirty Years War. Doing so, it decomposes a very long-run effect into a more digestible line of research. It employed the original idea and data from Prussia to show that geography is indeed not a destiny, and states with a 'bad geography' are not trapped in their development. State capacity can be imposed via short-run changes, and not only in the very long run. The effect of warfare on state development (Tilly (1975, 1993) and more recently Ko et al. (2014) hold, assuming that

military spending itself was a forerunner of other centralized government activities. The positive message of the result is that reforms, although based upon very-long run and steady events of state development, can introduce changes in rather short periods. It seems plausible that both very long-run effects of state development, the very long-run advantage that the Brandenburg soil provided the Hohenzollern's with, and radical events, such as the 'radical' reforms introduced under the reign of Frederick William, indeed work together and enlighten our understanding of political institutions and their role for economic development.

Geography provided Brandenburg-Prussia with a head start in the development of an effective taxation, but it did not shape its destiny altogether. Ex post, we can understand better why the nexus of military and nobility created a society that was different to other German and European counterparts. However, it is not the aim of this paper to support the claim of a direct link between the developments of the Prussian militarism to the further path of German history, as also Hitler himself tried to create it on the 'Day of Potsdam' in March 1933. In 1949, Prussia was sentenced to disappear from the map, in absence, as its institutions were already a victim of the Great Depression. This paper shed light on how it became a strong state in the seventeenth century. But as it ends there, and covers only a minority of the German population, there were plenty of other paths that German history could have chosen afterwards.

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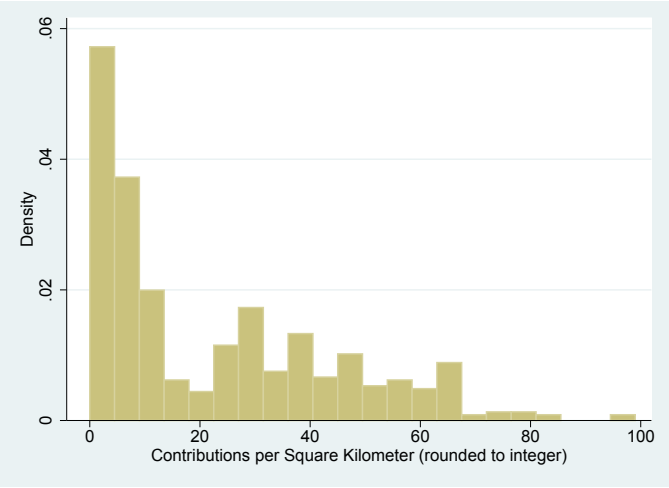
A. Summary Statistics

Table A.1

	(1)				
	count	mean	sd	min	max
Year	576	1673.5	13.86544	1650	1697
Contribution	554	94848.39	122253.5	0	600000
Contribution per Square Kilometer	554	21.52166	22.12231	0	99
Caloric Observability	576	-673.1845	231.6276	-387754.3	0
Caloric Suitability	576	1712.639	189.9811	1464.293	2048.509
Square Kilometer	576	8798.169	13159.48	165.1159	39286.55
Longitude	576	753786.2	260683.4	370343.7	1290058
Elevation	576	125.7935	57.6802	58.41158	247.4892
Ruggedness	576	37.25671	18.49699	17.74061	80.57219
Distance to Pottasium Salt	576	122.7333	148.353	3.191954	508.6799
Distance to Trade Roads	576	63.38237	82.52005	0	239.4516
Distance to Berlin	576	207207	122494.8	0	379521.1
Distance to Hanseatic Town	576	27.03602	21.83832	7.867209	87.36568
N	576				



Note: Histogram of contributions per square kilometer 1650–1797 in the data from Wolters (1915).

Figure A.1: *Histogram of Contributions per Square Kilometer*

*How Britain Unified Germany: Endogenous Trade Costs and the Formation of a Customs Union**

THILO R. HUNING† AND NIKOLAUS WOLF‡

Abstract

We analyze the foundation of the German Zollverein as an example how geography can shape institutional change. We show how the redrawing of the European map at the Congress of Vienna 1815—notably Prussia's control over the Rhineland and Westphalia—affected the incentives for policymakers to cooperate. Our argument comes in three steps. First, we show that the new borders were not endogenous to trade. They were at odds with the strategy of Prussia in 1815, but followed from Britain's intervention at Vienna regarding the Polish-Saxon question. Second, we develop a theoretical framework, where state planners set tariffs on imports and transits to maximize revenue. We show that in a world with transit tariffs a revenue-maximizing state planner faces a trade-off between benefits from cooperation and the cost of loosing geographical advantage. In a third step we calibrate the model combining historical data on tariffs, freight rates, market sizes with GIS data on lowest costs routes under endogenous tariffs. We then run counterfactuals to show how borders affected incentives: if Prussia would have succeeded with her strategy to gain the entire Kingdom of Saxony instead of the western provinces, the Zollverein would not have formed. We conclude that geography can shape institutional change. To put it differently, as a collateral damage to her intervention at Vienna "Britain unified Germany".

JEL Codes: F13 · F15 · F55 · N73 · D74

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Trade costs are large and highly persistent. Under fairly general assumptions can trade costs be decomposed into physical transportation costs, political border related trade barriers and retail and wholesale margins (Anderson and van Wincoop, 2004). However, as argued by Head and Mayer (2013) in their survey chapter in the Handbook of International Economics, the underlying determinants of trade costs remain poorly understood. A better understanding of those determinants is important, because the potential gains from a further reduction of trade costs depend on their nature. If for example a large part of trade costs stems from trade taxes, then a positive level of taxes may be optimal for some regions (Costinot et al., 2015). Instead, a reduction in physical transportation costs could benefit all regions. A recent literature has improved our understanding of physical trade costs, notably Allen and Arkolakis (2014) and Fajgelbaum and Schaal (2017). Both show in a general equilibrium framework how geography gives rise to a topography of physical trade costs. However, both do so under the assumption of a single central planner, hence no political trade costs.

In this paper, we ask how physical trade costs interact with political trade costs. Our starting point is that a country's trade cost are to some extent its neighbor's profit. To keep things as simple as possible, we use a partial equilibrium framework following Irwin (1998) with many revenue maximizing states. In contrast to Irwin (1998), states are not only constrained by demand but also by their physical trade costs. Some states have low physical trade costs (e.g. due to direct access to the sea), while others face high physical trade costs (e.g. if they are landlocked). Under very general assumptions of the underlying geography this gives rise to the issue of double or multiple marginalization, known from the literature on supply chains (Greenhut and Ohta, 1979) and spatial competition (Mathewson and Winter, 1983). We show first, that some states can increase their tariff revenue at the expense of their hinterland, depending on their respective physical trade costs. Second, we show that a customs union can be beneficial for a group of states, because it solves the problem of double marginalization. Finally third, we show that small changes in geography can have large, persistent effects on trade policy and institutions. We illustrate this mechanism with a prominent historical example, the formation of the German Zollverein in 1834. We show how changes in Prussia's geography after the congress of Vienna in 1815, which were imposed by Britain, forced the smaller German states into a customs union with Prussia. In this way, Britain

unintentionally helped to unify Germany.

The basic idea is not new. Already Adam Smith noted that"(t)he commerce besides which any nation can carry on by means of the river (...), which runs into another territory before it reaches the sea, can never be very considerable; because it is always in the power of the nation to possess that other territory to obstruct the communication between the upper country and the sea" (Smith, 1776, p. 19). In a nutshell, a state's sea and river access can lead to control over trade, revenues, and growth of other states in the hinterland. A major source of state revenue well into the 19th century originated from tariffs on trade flows. Until the Barcelona Statute of 1921 (Uprety, 2006, p. 48ff) these tariffs were levied on all trade flows passing a customs office, including transit trade. A state ruler, aiming to maximize tariff revenue therefore had to anticipate how tariffs would affect not only trade flows but also trade routes and tariff rates abroad, depending on geographic position. For example, if a transit tariff was set too high, traders attempted to use other routes and bypass the state. While transit tariffs have been abolished in 1921, states with a locational advantage continue to benefit from transit flows of third countries as service providers and locations with good access for industrial production. More recently, the growth of containerized trade since the 1970s has led to the emergence of hubs, which attract large volumes of transit shipments. We argue that then and now the resulting dependencies between states can increase the benefits from political cooperation between them.

Specifically, we show how our theoretical model can explain the economic and political unification of Germany during the 19th century, which fundamentally changed the European balance of power (Simms, 2013). It is remarkable that several small sovereign states such as Bavaria or Saxony, which had just escaped their elimination during the Napoleonic wars, started to give up parts of their sovereignty little more than a decade later to cooperate under Prussian leadership. We argue that this rise of Prussia to become the dominating power within Germany can be explained with our theoretical framework. With the new borders after 1815 Prussia held sway over both large continental transport systems before the age of the railway - most of the rivers Elbe in the East of Germany and the Rhine in the West feeding into the North Sea. This put other German states under pressure to follow Prussia into the Zollverein, a customs union under Prussian dominance. After Prussia formed a preliminary union with Hesse-Darmstadt in 1828, this pressure increased again

and by 1835 all German states placed between the two Prussian territories or to the South of them had joined into the Zollverein.

Our theoretical model can explain this result and the sequence of decisions that led to it. However, in the model with many states, the selected equilibrium is typically not pinned down by fundamentals but depends on the sequence of decisions. This is why our empirical strategy rests on a calibration and simulation exercise. We calibrate the model to historical and GIS data on territories, infrastructure, population and tariffs and show how the incentives of state planners changed in response to a change in state boundaries and varying coalitions. The key here is a thought experiment with counterfactual borders. We compare the factual borders of Prussia after 1815 (with two separate territories in the East and West of Germany and small gains from the northern part of Saxony) to a counterfactual with historical validity: a Prussian state in alternative borders according to the original plan of count Hardenberg, Prussia's negotiator at the congress of Vienna. According to this plan, a new Prussian state would have consisted of Prussia's eastern territories and the entire former Kingdom of Saxony, while the latter would have formed a new sovereign state on the territory of Westphalia and the Rhineland. We show that many German states had an incentive to join a customs union with the factual borders of 1815. Instead, with a counterfactual Rhineland state, the situation would have been very different. The same states would have had higher incentives to form a customs union with such a Rhineland state than with Prussia, while in turn a counterfactual Rhineland state would not have joined a counterfactual Prussia in a customs union. A customs union that would have encompassed both the eastern and western parts of Germany would not have formed. We also provide evidence that the result is robust to various alternative customs unions that were discussed at the time. As recently shown by Keller and Shiue (2014), the formation of the Zollverein had very large effects on the integration of markets. It prepared the monetary unification of German states within the boundaries of the Zollverein Holtfrerich (1993) and helped to pave the way to Germany's political unification in 1871 under the leadership of Prussia, if only by fostering Prussia's industry (Wehler, 1989, pp. 125ff).

Our paper is related to several strands in the literature, notably on trade costs and trade agreements, economic geography, nation building, persistence in economic development and not at least

the historical literature on the formation of the Zollverein. To start with, a recent literature has improved our understanding of trade costs (Anderson and van Wincoop, 2003, 2004). Important new contributions have considered physical trade costs, notably Allen and Arkolakis (2014) and Fajgelbaum and Schaal (2017). Both show in a general equilibrium framework how geography gives rise to a topography of physical trade costs. However, both abstract from political trade costs, because they assume a single central planner. Our paper explores how physical trade costs shape political trade costs. Related to this is the large literature on trade agreements, including Ossa (2011, 2012) and Antràs and Staiger (2012). These papers argue that trade agreements can reduce negative externalities from tariffs due to profit-shifting, firm-delocation or trade-volume externalities, beyond the older arguments based on terms of trade effects. For example, Antràs and Staiger (2012) discuss the implications of offshoring and resulting lock-in effects for buyers and sellers for trade policy. In their case, the fragmentation of production and trade into upstream and downstream firms gives rise to a hold-up problem that can be remedied by trade agreements. Instead, we abstract from fragmented production but focus on the relative geographical position of states and show how this affects incentives to coordinate tariff policy. Our setting also pioneers a more complex understanding of geography than what is typically considered. While the role of geographical distance and market access have been fairly well understood since the theoretical advances on the gravity model (Eaton and Kortum, 2002; Anderson and van Wincoop, 2003; Redding and Venables, 2004), the routing of trade has been typically ignored in the recent literature. In contrast, routing plays an increasing role in the literature on operational research and logistics in the face of increasingly fragmented production processes (e.g. the survey by Nagy and Salhi (2007) on the so called location-routing-problem). In our framework, trade routes are crucial for tariff policy.

The literature on economic geography in the wake of Krugman (1991) has analyzed how 'first nature geography' such as access to the sea or climate can affect 'second nature geography' such as the emergence of economic agglomerations and patterns of core and periphery. But these models remained highly stylized and were of limited use for empirical research. The more recent application of quantitative models of international trade (notably Eaton and Kortum (2002)) to the study of economic geography allowed to derive new hypotheses on the spatial distribution

of economic activity and directly test for them (e.g. Donaldson (2016), Ahlfeldt et al. (2015); see the survey by Redding and Rossi-Hansberg (2016). Related to this, we derive a theoretical model that can be calibrated to historical data and simulated to assess its explanatory power. Moreover, trade costs are typically treated as exogenous in the recent literature on economic geography. In our framework, exogenous physical trade costs lead to much larger endogenous political trade costs.

Next, our paper is related to the recent literature on nation building and endogenous political borders in the wake of Alesina and Spolaore (1997) and Bolton and Roland (1997). Both papers argue that there is a basic trade-off between the benefits of larger jurisdictions and the costs of that size. Alesina and Spolaore (1997) show that the benefits from economies of scale and scope of larger jurisdictions have to be balanced against the political costs of heterogeneity. Bolton and Roland (1997) also consider the benefits from economies of scale and weigh them against the loss of control on political decisions at the local level. An emerging literature analyzes the factors that changed these trade-offs in the long-run, notably military rivalry (Aghion et al., 2012) and war-related institutional change Acemoglu et al. (2011). We add to this literature by showing how geographical constraints can affect the cooperation between sovereign states and induce long-run institutional change.

Another strand in the literature on which we draw and to which we contribute is on the role of history for economic development. In his survey on the topic Nunn (2009) stresses the prominent role of geography for economic outcomes via its impact on past events. As argued by Engerman and Sokoloff (1997, 2002), differences in soil quality and climate may have shaped the incentives of elites to foster education systems. Related to this is the argument that variation in the suitability of land for growing potatoes affected the growth of population and cities, with persistent effects until today Nunn and Qian (2011). We extend a long-standing argument that access to waterways and relative geographic position affected the incentives to cooperate between states and their ability to impose certain policies on each other (Mahan (1890); Mackinder (1919) and more recently Simms (2013) and Kaplan (2012)). Our paper is therefore related to Redding et al. (2011) and Bleakley and Lin (2012) on geographical lock-in and Michaels and Rauch (2013) on the long-run effects of geographical fundamentals for the dynamics of urban networks.

Last but not least, several authors have tried to explain the emergence of customs unions and in particular that of the Prussian Zollverein. In his work on the economics of customs unions Viner (1950) already considered the Zollverein to be the "pioneer and by far the most important customs union". There is a small but prominent historical literature on the formation of the Zollverein. In his seminal work on the Zollverein, Dumke (1976) considered several possible motives for joining the Zollverein. He argued that by joining the Zollverein German states could hope to benefit from economies of scale in the collection of tariff revenues, benefit from a larger market for industrial products (i.e. Smithian growth), while simultaneously staying in control over these revenues. Dumke (1976) provides several pieces of descriptive evidence to support his argument but he cannot directly test it. Next, Ploeckl (2010) explores in an insightful study the negotiations over Zollverein membership and argues that Prussia could act as an agenda setter in a bargaining game. In particular he provides descriptive evidence for the hypothesis that Prussia negotiated sequentially with German states over their membership in order to maximize coalition externalizes on states still outside the union. Finally, Keller and Shiue (2014) estimate the effect of the Zollverein on the integration of grain markets, taking into account that the incentives to join were endogenous to ex ante trade, similar to Baier and Bergstrand (2007). They use a state's average distance to the coast relative to average distance to the coast of non-member states as an instrument to control for the endogeneity of Zollverein membership and find that joining the Zollverein had a substantial causal effect on the integration of grain markets. Our contribution to this literature is twofold. First, we provide a new theoretical framework that can be seen as a synthesis of these ideas but matters beyond the specific historical context of the Zollverein. Second, we are the first to trace the specific formation of the Zollverein back to the exogenous change in political borders at the congress of Vienna in 1815.

We proceed in this paper as follows. In section a we introduce our historical example of the formation of the German Zollverein. In section b we motivate our theoretical approach giving descriptive evidence. In section c we present our theoretical framework. We start with a very basic framework on the role of geography for a revenue maximizing state that is step by step generalized. In section d we discuss our empirical strategy, describe our data and explain how we used historical data and GIS data to calibrate and simulate the model. Section e. contains our main results on

the fit and explanatory power of the model. We show how the model can capture the sequence of events that led to the formation of the Zollverein. We also show that under counterfactual borders the Zollverein would not have formed. We conclude in section f.

A. FROM THE CONGRESS OF VIENNA TO THE ZOLLVEREIN

We will apply our theoretical framework to the formation of the Zollverein. In a broader context, it is well known that the success of some places is not only induced by their local characteristics, but their position relative to others. In a recent study Michaels and Rauch (2013) show how network effects mattered for city dynamics in the very long-run. German history after 1815 provides us with a quasi-experiment on a similar type of network effects for sovereign states rather than individual cities. First, we will outline why we consider the events at the Congress to be exogenous to economic rationale, notably to trade. Second, we will explain why trade costs should be treated as endogenous for the period under consideration. This includes a discussion on the role of tariffs and transit trade for government revenues. Third, we will discuss the role of the Rhine. Forth, we will discuss some of the dynamics that led up to the formation of the Zollverein, including failed attempts to form alternative customs unions. In our empirical section we will use our model to replicate these dynamics.

1. Great Power Politics at the Congress of Vienna

At the end of the Napoleonic wars 1792–1815 only Russia and Great Britain had emerged as major military powers. Habsburg, Prussia and the defeated France attempted to consolidate their position at the expense of the many smaller states that had survived the recent wars, notably the former allies of Napoleon such as Saxony or Poland. A central object of the negotiations at Vienna was the redrawing of the European map, especially the so-called Polish-Saxon question. Overall, the negotiations were dominated by military-strategic considerations between the two great powers. By hindsight, economic aspects and the position of Prussia were both of minor importance to the

outcome of the congress. Alexander I. of Russia aimed for a double-monarchy of Russia and Poland. This expansion of Russia to the West met stiff opposition from Britain and Habsburg. Britain's ambassador Castlereagh warned his Prime Minister that this "would have the colour of an attempt to revive the system we all united to destroy, namely one colossal military Power holding two powerful States in a species of dependence and subjection, and through them making her influence in the remotest parts of Europe" (Müller, 1986).

Prussia's chancellor Hardenberg, who led the Prussian delegation at Vienna, pursued predominantly military-strategic aims[1]: In order to ease the defense of its territory and capital, he intended to finally annex the Kingdom of Saxony (Clark, 2007, p. 389). Castlereagh consented under the condition that Prussia would support the British position in the Polish Question[2], so does Metternich[3]. Under the leadership of Castlereagh, the three formed an informal coalition against Russia. However, Prussia left this alliance under pressure of Alexander, because Russian troops had occupied Saxony (Burg, 1993, p. 12ff.). In a desperate move to secure the Saxon territory for Prussia, Hardenberg offered in late 1814 to relocate the entire court of Saxony to the Rhine including "a city pleasantly situated at the Rhine, suitable for a residence" for the Saxon king (Müller, 1986, p. 262). As this offer was rejected, Hardenberg, seeing the Prussian position decaying between the Tsar's plans and 'British interest', threatened with a new war. The response was a defense alliance between Great Britain, Austria and France against Prussia and Russia and a serious risk of a new war in late 1814 (Burg, 1993, p. 27).

Ultimately, the Congress ended as a big compromise, shaped very much by the attempt of Great Britain to contain Russia's westward expansion. Poland was divided (again) between Russia ('Congress Poland'), Prussia and Austria. Also, Saxony was divided in two parts. The Kingdom of Saxony was shrunk to its southern part, while the northern part formed the new Prussian province of Saxony. As compensation, Prussia was also given the Rhineland and Westphalia in the West, to become the "warden of the German gate against France"(Clapham, 1921, p. 98). Figure 1 shows the map of Germany after 1815.

[1]This military-strategic argument was already developed by Friedrich II (1712–1786), probably during the Seven Years War (1756–1763). In his notes "par droit de bienséance", he outlines the territory of Saxony as key for the defense of Berlin (cited after (Mittenzwei, 1985, p. 209).

[2]Note from Castlereagh to Hardenberg, October 11th 1814 (Müller, 1986, p. 211).

[3]In his note, Metternich consents as long as Habsburg would keep its influence within Germany. Note to Hardenberg, October, 22nd (Müller, 1986, p. 214 f.).

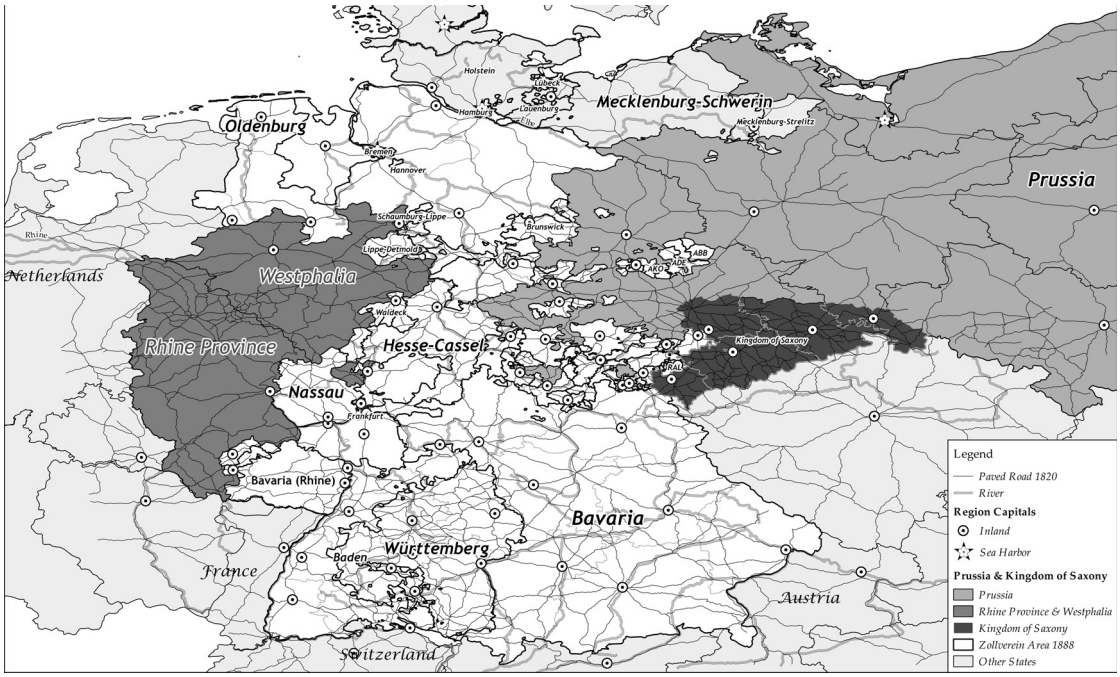

Figure 1: *Map of the German lands after the Congress of Vienna including the rivers and the 1820 road network. Hesse-Darmstadt is the state just South of Hesse-Cassel.*[4]

As Clark (2007, p. 389) concludes, "Berlin failed to get what it wanted and got what it did not want.[...] The creation of a large Western wedge along the river Rhine was a British, not a Prussian, idea.". The German Bund was established as a loose federation of German countries under the joint leadership of Habsburg and Prussia (Hahn, 1982, p. 127).

2. *Transit Tariff, and Structure of Trade*

While the Congress of Vienna settled the large geopolitical issues, most German states still faced existential threats after 1815. To start with, after years of war and territorial changes back and forth and indeed after financial difficulties inherited from the pre-Napoleonic era, state finances were out of control Borchard (1968). What was needed was fundamental administrative reform and new sources for revenue. Prussia, pressed very hard after the defeat in 1806, had started a series of reforms, including a fundamental reorganization of the administration, agrarian reforms, changes in the educational system and some first attempts to reform taxation. But still in 1821, six

years after the war, the ratio of Prussia's government debt to total state income stayed above 400 percent (Mieck, 1992, p. 124). A major step towards a new financial system was Prussia's tariff law of 1818, which abolished all internal tariffs and established one common tariff along the external border following the examples of France and Britain Onishi (1973). This and the introduction of a class-wise income tax system helped to consolidate Prussia's state finances in the following decades and put other states in Germany under pressure to react. However, the main challenge from a Prussian perspective was to connect the two separate territories in East and West for both administrative and strategic reasons. In this Prussia faced resistance from smaller states who feared to loose their independence. It turned out that the main asset of Prussia in this was her geographic position for trade policy.

Trade policy was at center stage for government revenue at the time. In Central Europe, trade flows had to pass often a dozen of tariff borders even on relatively short distances. This was considered by many contemporaries to be a main disadvantage compared to politically unified territories such as France or the United Kingdom. As shown in the theoretical section the fact that tariffs were usually also levied on transit trade until the Barcelona Statute of 1921 (Uprety, 2006, p. 48ff) had far reaching implications for tariff policy at large. Prussia's tariff law of 1818 forced traders to detour the large territory, or accept the tollage. As Clapham puts it, "The analogy between the King of Prussia and some robber baron of the middle ages could not but occur to the least learned pamphleeter." (Clapham, 1921, p. 99). In turn, for states on the detour routes, such as the Hessian states, this was a large source of income.

Traders were often willing to pay transit tariffs, because they lacked alternatives. In the early 19^{th} century, these alternatives were mostly determined by geography. Transport on water was much cheaper than transport over land. According to Sombart (1902), the average freight cost per tonkilometer during early 19th century Germany on river was between 0.6 and 1.5 percent of the average freight cost on country roads. The main instrument to improve the transport infrastructure apart from building canals was to construct paved roads with a fully developed drainage system ("Chausseen") that made them usable even during bad weather conditions. This could bring down average freight cost per tonkilometer to 25 percent of that on standard roads. Railroad construction started in Germany only in 1835, where most lines were built in the two decades after 1848. But

road construction was expensive and time-consuming, hence no option in the short-run.

The multitude of tariff barriers also had consequences for the type of goods that could be traded over longer distances. In 1829, almost 80 percent of the value in exports from Amsterdam upriver originated from only two goods: coffee, and sugar (Kutz, 1974, p. 341). Wine was another important item. These three goods, sugar, coffee, and wine could be traded in spite of the high trade costs, because their import demand was highly inelastic. First, they faced only limited competition from local substitutes. Sugar beet production on a significant scale started only in the late 1830s in Germany, and required initially government support. Domestic produce of wine and spirits accounted only for a seventh of demand (Dieterici, 1846). Coffee, unlike tobacco that accounted for half of domestic demand (Dieterici, 1846), could not be grown in Germany. Second, all these goods are 'drug-alike', which suggests that demand should respond relatively little to variation in prices. What Ferguson noted for the British Empire was similarly true for the German lands: "the empire, it might be said, was built on a huge sugar, caffeine and nicotine rush – a rush nearly everyone could experience." (Ferguson, 2002). According to Onishi (1973) these three goods alone accounted for more than half of Prussia's revenues from tariffs in the 1820s.

3. The Role of the Rhine

Navigable rivers attracted the bulk of all trade flows due to their much lower physical transport cost per ton-kilometer. However, river banks were historically fragmented. Adam Smith noted that "the navigation of the Danube is of very little use to the different states [...], in comparison of what it would be if any of them possessed the whole of its course till it falls into the Black Sea" (Smith, 1776, p. 19). This is especially true when states maximize revenues. One single state can harm all others' revenues, and credible commitment makes everyone better off—a classical prisoner's dilemma[5]. Wilson (2016, p. 469) views the inability to coordinate Rhine states as a major failure of the Holy Roman Empire. Running through over 30 toll stations, much of the Rhine trade was eventually rerouted overland, notably through the Hessian hills.

Napoleon's unification of several Rhine states into Westphalia and the Rhineland was a first step

[5]See also Bagwell and Staiger (1999). An interesting note is that their theoretical debate on optimal tariffs is dependent on the assumption of either a small or a large country setting tariffs, in terms of whether the tariffs will shift world prices. In our framework, even the smallest state can affect prices in other states, depending of it's geographical position.

to address the problem of fragmentation. Soon after 1815 Prussia had gained control over much of the Rhine, it was realized that the Rhine would be a substantial source of revenue, if the tariff levels could be lowered and unified. Hans, Count of Bülow, minister of finance, noted in 1817 that "The long coast, the location of the Rhenish and Westphalian provinces between France, the Netherlands and Germany, make this country very suitable for transito. The greater the freedom, the more trade one will be able to seize."[6]. This outlines a central motive of Prussia—exploiting the geographic position to raise tariff revenues *induced by, and not in spite of* trade liberalization. Central to this is an understanding that multiple taxation reduces overall revenue, because of multiple marginalization. However, still after 1815 trade on the Rhine was subject to a multitude of political trade costs such as tariffs and duties payable at Rotterdam or staple rights and the requirement to use specific shipping companies for parts of the voyage (Spaulding, 2011). One event that contributed to a further reduction in tariff fragmentation along the Rhine was the Belgian revolution in 1830/31. The (prospective) independence of Belgium from the Netherlands and the rise of Antwerp as a competitor to Rotterdam limited the bargaining power of the Netherlands and helped the negotiations between the various riparian states to reduce tariffs along the Rhine. As a consequence, after 1831 more traders used the Rhine and less trade was routed over land through the Hessian states, notably through Hesse-Cassel (Hahn, 1984, p. 60).

4. Failed Unions and Agreements

The small German states' debt called for immediate action after the Napoleonic Wars. The main source of new revenue had to be taxation, given that the revenue from state monopolies and state-owned farms or factories could not be easily increased at the time (Ullmann, 2005, p. 34). However, smaller states must have feared that by joining the Prussian Customs Union, they gain revenue at the risk of giving up sovereignty towards Prussia. The option to form a free trade area rather than a customs union, which would have allowed states to set their external tariff independently, was not viable at the time, due to difficulties to implement a rule of origin in the fragmented German state system (Ploeckl, 2010). The perceived solution of this problem seemed to be a customs union without Prussia. And indeed, the 1820s witnessed several attempts to form

[6] cited after (Dieterici, 1846, p. 64); own translation.

such customs unions. Bavaria, Württemberg, Baden, and two Hessian states signed already in 1820 a preliminary agreement to take up negotiations on a customs union excluding Prussia and Austria alike. However, the negotiations did not succeed, mostly because it was unlikely to pay: the interests of Baden and Hesse-Darmstadt diverged too far from those of Bavaria and Württemberg. Calls upon Austria in the early 20's to lead a tariff union, prominently put forward by Friedrich List, were turned down, as Austrian trade was mostly directed in the flowing direction of the Danube (Hahn, 1984, p. 31). The only tangible result was the formation of a customs union between Bavaria and Württemberg in January 1828.

In the meantime, the small state of Hesse-Darmstadt had started to turn to Prussia, which should change the situation fundamentally. A look at the maps suggests why. The two Prussian territories in the East and in the West were separated by the two states of Hesse-Darmstadt and Hesse-Cassel. The financial situation of Hesse-Darmstadt was considered to be the worst among all German states after 1815. The small state itself was divided into two territories and economically more dependent than others on the neighboring Rhineland, now under Prussian control. A first push of Hesse-Darmstadt in 1825 was rejected by Prussia on the grounds that only a simultaneous agreement with both Hessian states would be attractive for the Prussian side. But Hesse-Cassel was much less pressed and actually benefited from trade diverted away from the Rhine. In 1827 Prussian negotiators started to realize that the desperation of Hesse-Darmstadt was a strategic opportunity. In the negotiations during that year, Prussia was eager to be as benevolent as possible towards Hesse-Darmstadt. In exchange to Hesse-Darmstadt's agreement to adopt the Prussia customs law of 1818, in February 1828 the two states formed a customs union between two equal sovereign partners, where changes in tariff policy would have to be agreed unanimously (Hahn, 1984, p. 46). The strategic value of this can be seen in the externalities of this Prusso-Hessian customs union on other states, foremost on Southern Germany. As this was rightly considered as a first step of Prussia to connect its two territories, the reactions across German states as well as in Vienna, London and Paris were quick and desperate. In September 1828, Hanover (still in personal union with the United Kingdom), Saxony, Hesse-Cassel, Nassau, the free city of Frankfurt, and the Thuringian States signed a contract—on not signing contracts with anybody else (Hahn, 1984, p. 50). Also, the governments of Bavaria and Württemberg tried to contain a further expansion of Prussian influence,

because they realized their growing dependency on Prussian tariff policy. However, already in late 1828 they gave up. The Bavarian government started to negotiate an agreement and eventual merger between the customs unions of Bavaria-Württemberg and Prussia-Hesse-Darmstadt. The reduction of tariffs on the Rhine in the wake of the Belgian revolution helped to convince the government of Hesse-Cassel to join the union of Prussia and Hesse-Darmstadt, which completed the territorial link between the two parts of Prussia in August 1831. As this was a breach of the treaty of September 1828, Habsburg in an Alliance with England attempted to sue Hesse-Cassel over this on the courts of the German Bund in a last attempt to stop the Prussian victory. But economic incentives proved to be stronger. In autumn 1833 the Southern Customs Union was merged with the Prusso-Hessian customs union and enlarged by others, including Saxony and the Thuringian states. Baden followed in 1835, Brunswick in 1841 and even Hanover joined in 1851, Oldenburg a year later. Only states with direct access to the sea stayed out before the formation of the German Empire in 1871.

Habsburg's chancellor Metternich always considered the Zollverein as a tool to establish Prussia's dominance in Germany and tried to prevent its formation (Mieck, 1992, p. 163). By hindsight, he was right. While we do not claim that the Zollverein determined Prussia's way to become hegemon within Germany, it was clearly instrumental in this process. The Zollverein helped Prussia to consolidate its new territory and use the benefits from the industrializing regions in the West for its rise as a military power. In the next section we show that our theoretical model can explain many of these historical facts: how the customs union between Bavaria and Württemberg mattered for Prussia, why the customs union between Prussia and Hesse-Darmstadt increased pressure on the remaining states in Central and Southern Germany, why this pressure was more limited for states closer to the coast. Crucially, the model also highlights that a different outcome of the Congress of Vienna, one without British intervention, would have likely prevented the formation of the Zollverein altogether.

[6] Abbreviations: ABB: Anhalt-Bernburg, ADE: Anhalt-Dessau, AKO: Anhalt-Köthen, HHE: Hohenzollern-Hechingen, HHO: Hess-Homburg, HSI: Hohenzollern-Sigmaringen, REB: Reuß-Ebersdorf, RGA: Reuß-Gera, RLS: Reuß-Lobenstein, RSC: Reuß-Schleiz, SGA: Saxony-Gotha-Altenburg, SHH: Saxony-Hildburghausen, SCS: Saxony-Coburgurg–Saalfeld, SRU: Schwarzburg-Rudolstadt, SSO: Schwarzburg-Sondershausen, SWE: Saxony-Weimar-Eisenach.

B. DESCRIPTIVE EVIDENCE

Table 1: *Descriptive statistics of the year the 34 German states that would join the German Zollverein*

	Dependent variable: Year the Zollverein membership was contracted in								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Transit Through Prussia	-29.51***	-14.74*	-16.64**	-16.98**	-24.91***	-12.92*	-16.81**	-17.00**	-15.58**
	(4.023)	(5.599)	(5.337)	(5.308)	(6.103)	(5.146)	(5.469)	(5.354)	(5.494)
Std. Distance to Oceans		-7.624**	-7.935***	-8.096***	-11.46*	-8.731***	-7.897**	-8.042***	-8.273***
		(2.258)	(2.130)	(2.119)	(4.890)	(1.992)	(2.170)	(2.126)	(2.174)
Std. Distance to Rivers			-4.241*	-4.519*	-6.273***	-4.069*	-4.300*	-4.379*	-3.808
			(1.897)	(1.898)	(1.323)	(1.753)	(1.942)	(1.902)	(1.968)
"Cultural Heritage"				✓					
Absolute Monarchy						-7.900*			
						(3.037)			
Constitutional Monarchy						-2.511			
						(2.963)			
Std. Length of Border							0.717	-6.276	
							(2.967)	(5.475)	
Std. Area								12.68	
								(8.418)	
Std. Length of Border Per Area									1.188
									(1.366)
Constant	45.83***	34.61***	35.26***	36.60***	49.48***	35.77***	35.53***	37.40***	34.29***
	(3.651)	(4.595)	(4.334)	(4.449)	(4.657)	(4.077)	(4.544)	(4.617)	(4.490)
N	34	34	34	34	34	34	34	34	34
Adj. R^2	0.615	0.710	0.743	0.746	0.906	0.781	0.735	0.746	0.741
AIC	247.4	238.8	235.5	235.9	208.0	231.7	237.4	236.8	236.6

Note: This table depicts the significance of the fact that a state's imports from the Atlantic have to pass via Prussia on the least-cost-path from London, assuming there would be no transport costs except to move the goods physically. All variables indicated 'Std.' are standardized to mean zero and standard deviation of one. Standard errors in parentheses. Significance levels are indicated as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Summary statistics of all variables are provided in table 5 of the appendix.

To motivate our formal analysis, consider table 1. Our dependent variable is the year that any of the 34 German states signed a treaty to join the Zollverein. Using the standard Dijsktra algorithm, we calculated least cost paths, assuming that there would be no political costs (e.g. tariffs) to ship any good from the Atlantic economy (which we proxy with London) to any other region. We then generate other variables from GIS using states and roads from Kunz and Zipf (2008), and rivers from the European Environment Agency[7]. The variable *Transit Through Prussia* is then coded one if the territory of Prussia is crossed on this least cost path, zero otherwise. This simple variable

[7]The data can be downloaded here: `https://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes`

alone explains over 60% of the variation, and its negative estimate indicates that states whose transit would flow through Prussia would join the Zollverein earlier. This finding is robust if we control for other geographic indicators.

Keller and Shiue (2014) employ distance to oceans as an instrument. *Distance to Oceans* measures the distance between 1,000 random points generated within the state and the closest ocean in kilometer[8]. As all variables indicated 'Std.', this distance variable was then standardized to a mean of zero and a standard deviation of one. Regression (2) shows that states with better access to the ocean would join the Zollverein later. As indicated by the smaller effect of the transit through Prussia, these two measurements relate, but also have joint explanatory power. In this regression, the fact that a state's transit goes via Prussia is equivalent to almost a two standard deviations change in the distance to oceans. This means that a state that differs from any other state just due to the fact that the least cost path to the Atlantic Economy passes via Prussia behaves as if it was about 250 km further away from the sea. The significant result for *Distance to Rivers*, calculated analogous to its oceans counterpart using navigable rivers only, in regression (3) indicates that water transport in general mattered for the question of joining the Zollverein, and that better access to waterways would make states more reluctant to join. The effect of a standard deviation change of this variable is about half the effect estimated for the ocean. On the one hand, river transport, if it was downstream, was cheaper than ocean transport per ton-kilometer (see tab. 6 of the appendix). On the other, it is limited to trading partners on the same rivers and connection to world markets still dependent on sea harbors. The population of the states is not statistically relevant (column (4)). To control for the fact that some states look back at different cultural traditions due to their different heritages as Bavarian, Saxonian, Brandenburgian, or Hessian, we employ the 1150 map of the Holy Roman Empire from Huning and Wahl (2017), which leads to a vast increase in the model's saturation. The estimate for the Prussian transit is however even higher. This could capture the idea that the Saxonian and Thuringian states indeed could have found it easier to coordinate their decision based upon their common backround. This might have shifted the individual states joining by some years, however large alterations are unlikely. This map features 32 regions in Central Europe and is included as control variable in column (5). It has been proposed (Onishi,

[8]This procedure makes this indicator robust against different sizes of states, as larger state by chance would have some point very close to the ocean.

1973) that the Zollverein generated revenues that passed parliamentary control. Therefore, the political system should be relevant for the joining decision. Out of all categories for the political system in the dataset by Kunz and Zipf (2008), only the dummy variable for absolute monarchy shows up significant, suggesting that absolute monarchs would join earlier. Finally, we test the idea by Dumke (1976) that the Zollverein was a tool to reduce the costs of tariff border protection. In regression (7), the length of the state border in kilometer shows a very low estimate and is also not significant. The same is true for the area of a state in square kilometers (column (8)) and the division of border length and area as propounded by Dumke.

These results indicate a strong relationship between the relative geography of Prussia for the timing the German states joined Zollverein. However, we have to invest in theory to understand why this is the case, and we also have to realize that the sequence of joining is heavily endogenous. Many states join in 1833, and states also do not join independent from each other. While we grasp that the decision of one state is therefore not only dependent on Prussia, but on other states they trade with or other states their trade has to transit.

C. THEORETICAL FRAMEWORK

The theoretical framework explains the role of geography for revenue-maximizing countries, and their benefits from cooperation. We start off with the framework by Irwin (1998). Free on board (f.o.b.) prices are exogenous, such that tariffs[9] are in the end paid for by consumers, demand is linear and reacts to the tariff as part of the price.

Irwin (1998), as most common literature, limits his analysis on two countries where one country is the producer and the second the consumer. We extend this and assume that all countries face a given world supply, where one country's imports are its neighbour's transits. This induces room for cooperation in customs unions. In our model, all transit countries face multiple trade-offs in

[9]Think of any costs that a country can set and adds to the price of the good. The framework captures not only costs de jure codified as tariffs. Transit trade was subject to all kinds of taxes, tolls, and fees, which countries gained revenue from. Larger countries, such as Prussia (Onishi, 1973) or Bavaria (Schlögl, 2002, p. 139), aimed at simplifying this structures. Traders will account for non-monetary political costs of transport, such as staple rights, and include them into the price of the good. An example here is Hamburg. While de jure tariffs are absent Dumke (1976), harbor fees and a variety rights induce costs to traders, and therefore have a monetary equivalent.

their attempt to maximize their tariff revenues, and their decisions depend on geography. We introduce the concept of multiple marginalization known from industrial organization (see Church and Ware (2000)) to the optimal tariff literature and the foundation of customs unions. Multiple marginalization occurs when any product is manufactured by a revenue-maximizing producer using raw-material (called upstream) from a revenue-maximizing supplier (called downstream). In our context, if a country is an enclave of a second country, its tariff policy is like that of a downstream producer facing an upstream monopolist. Decisions to join a customs union can be analyzed in analogy to decisions about mergers & acquisitions.

We treat physical trade costs as exogenous, and concentrate on the effect of political trade costs, tariffs [10]. Migration occurred mostly towards Prussia and Northern German states, so that we can neglect its effect—it would only strengthen our argument. Moreover, we simplify the analysis assuming that state's cannot discriminate between imports and transits and hence set only one tariff rate for both. If states could discriminate tariffs, this would strengthen the position of upstream states and again only strengthen our argument.

1. One Country

Consider a world of many small countries facing given world supply. With respect to the small geographic scope of our analysis, assume similar preferences, uniform income distribution, and equal price elasticity of demand across countries. Consider a representative good that does not have any domestic substitute (historical examples would be coffee or sugar). Demand for this imported good $M_i \geq 0$ in any country i is linear and given by

$$M_i = D_i - ap_i \tag{1}$$

[10] First, before the emergence of the railway, due to the vast technological advantage of sea and river transport, sea harbors and river access were the most important geographic advantage. This implies that strategic building of infrastructure before the 1840s as described in Thimme (1931), had only have minor effects. Recent research, for example Fajgelbaum and Schaal (2017), has proposed general equilibrium frameworks with endogenous physical transport costs, which could be an interesting extension for future work. Second, the existence of transit tariffs and therefore manyfold taxation of goods within 19th century Germany was evidently more important than even the high physical transport costs of that time Onishi (1973)

$D_i > 0$ stands for the size of the market in i, and $a > 0$ stands for the elasticity of demand w.r.t. price at location i, $p_i > 0$. Markets are perfectly competitive. Transport of the good from w to i comes with positive per-unit cost $cost_{wi}$. These costs are specific (non-iceberg). Traders are fully informed and cost-minimizing at no arbitrage. Assume there exists a route r which bears the minimum costs out of all routes W_{wi} connecting w and i, which traders would use exclusively. This yields

$$p_i = p_w + \min_{r \in W_{wi}} (cost_r). \tag{2}$$

There are two types of transport costs between w and any i: Physical transport costs and political costs (tariffs). Physical costs $\phi > 0$, the costs of actually moving one unit of good, are exogenous and always positive. They need not to be symmetric, so that $\phi_{wi} \not\equiv \phi_{iw}$. Political transport costs t_i, which are costs associated with the crossing of any border of country i are endogenous to the framework, and will be in focus later. To this point, just assume they are also specific, per-unit. The list of countries on a route is given by $r = (r_1, .., r_{|r|})$. Assume that countries are just points in space (bearing no area), and that these points are connected via different routes. For any two countries i and j, the costs of any route r in W_{ij} is the sum of all physical and political costs,

$$r \in W_{ij} \Rightarrow r_1 = i \text{ and } r_{|r|} = j \qquad cost_r = \sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} + t_{r_n} \right). \tag{3}$$

while $r_1 = i$ and $r_{|r|}$ is always j. There is no smuggling, so there cannot be any route around the border of the destination country.

Following Irwin (1998), countries choose the tariff rate that maximizes their tariff revenues. This case represents a country with direct access to the source of production, without any other countries possibly interfering with its trade with world markets, and also without any other countries downstream of it. Any such "island" country i can gain revenue by charging a tariff t^I_{ig} such that it maximizes revenue

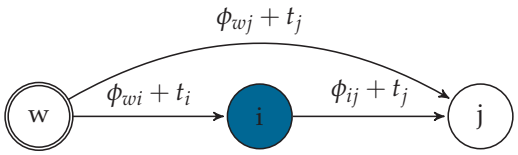

Figure 2: *Two countries and the world. If the direct edge from w to j is more costly than via i, i gains potential revenue. If wj would be infinitely expensive, j would be an enclave of i.*

$$R_i^I = \max_{t_i^I} \left(t_i^I M_i \left(t_i^I \right) \right). \tag{4}$$

.

This revenue-maximizing tariff t_{ig}^I, which we will call "'island tariff"' is retrieved by inserting equations 1 – 3 into equation 4, and taking the first derivative w.r.t the tariff rate,

$$\frac{\partial \left[t_i^I \left(D_i - a \left(p_w + \phi_{wi} + t_i^I \right) \right) \right]}{\partial t_i^I} = 0 \Leftrightarrow t_i^I = \frac{D_i - a \left(p_w + \phi_{wi} \right)}{2a}. \tag{5}$$

2. Two Countries

Add a second country as in figure 2. Now it depends on the geographical parameters how the two countries will set their tariffs, whether there will be transit trade or no transit trade, and how much revenue countries gain from tariffs. In the most simple case, both countries' have direct access to world markets at the same costs ($\phi_{wi} + t_i + \phi_{ij} + t_j = \phi_{wj} + t_j$). There is no upstream-downstream relationship, and hence no transit trade—countries' tariff revenue is only restricted by their own import demand.

(i) Revenue-Maximizing Tariff With Two Countries

Now assume that ϕ_{wj} would be very expensive. For example, imagine i being located at the sea, and j is landlocked and only connected to world markets via i. With this geography the

optimization problem translates to a standard problem from industrialial organization literature, multiple marginalization (see Church and Ware (2000)). Country j knows that its consumers will have to bear the price of the tariff, and sets the optimal tariff solving for (analogously to equation 5)

$$\frac{\partial \left[t_j \left(D_j - a\left(p_w + \phi_{wi} + t_i + \phi_{ij} + t_j\right)\right)\right]}{\partial t_j} = 0 \Leftrightarrow t_j = \frac{D_j - a\left(p_w + \phi_{wi} + t_i + \phi_{ij}\right)}{2a}. \tag{6}$$

Country i would react to this setting the tariff allowing for transits to j, t_i^j by setting up its revenue function's first derivative w.r.t t_i^j,

$$\frac{\partial \left[t_i^j \left(D_i - a\left(p_w + \phi_{wi} + t_i^j\right) + D_j - a\left(p_w + \phi_{wi} + t_i^j + \phi_{ij} + t_j\right)\right)\right]}{\partial t_i^j} = 0, \tag{7}$$

replacing t_j from equation 6, and set its own tariff such that

$$\left[t_i^j \,\middle|\, \phi_{wj} \to \infty\right] = \frac{\frac{2}{3}D_i + \frac{1}{3}D_j - a\left(p_w + \phi_{wi} + \frac{1}{3}\phi_{ij}\right)}{2a}. \tag{8}$$

Compare this tariff with the island tariff from equation 5. The resulting tariff can be higher, or lower than the island tariff, depending on the relative size of the countries, and the transport costs ϕ_{ij}. The larger D_j is relative to D_i, the higher the tariff t_i^j. Neglecting relative size (e.g. $D_i = D_j$), the larger transport costs from w to j relative to w to i (since $\phi_{ij} > 0$), the lower is t_i^j.

(ii) The Trade-Off of an Upstream Country

We understand in the absence of costs of a detour around i, there will be no transit trade, and if it is infinitely expensive there will be either transit trade or no demand for imports in j at all. We therefore established the detour costs as a central variable in the optimization problem. Let's define the difference between the least-cost-path including a set of countries, and the least-cost-path that

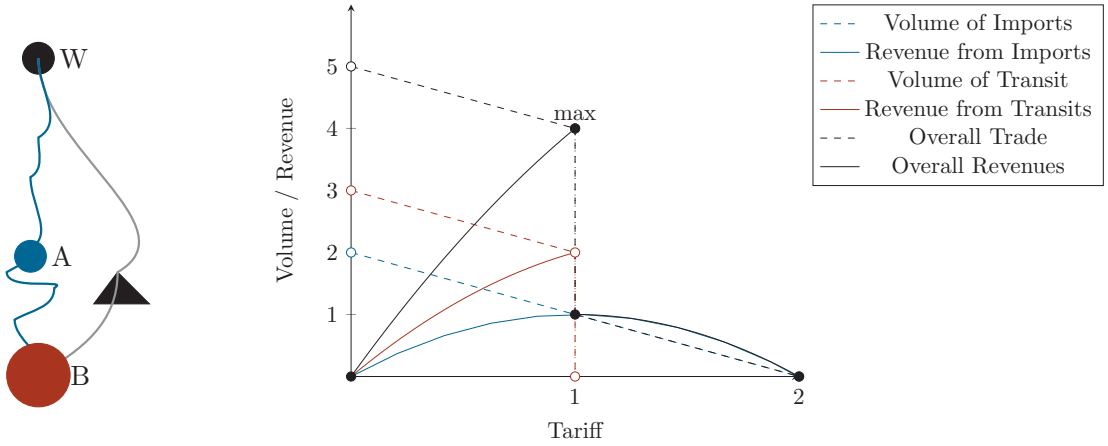

Figure 3: *The left sketch shows the stylized geography of two countries A and B, in which there is demand for products from the world W. The blue line indicates a river that allows transporting one unit cheaper than via the land road (indicated in gray). The optimization of country A is depicted in the graph on the right. A has initial domestic demand (imports, dashed blue), indexed to one. Country B's demand satisfied via A is depicted in dashed red. With any one unit increase in tariffs, consumers react by demanding one units less. A can get revenues from imports (solid blue), and transits to B (solid red). Overall trade, the sum of imports and transits, is depicted in solid black. From our assumptions on geography, it follows that at any tariff above one, transit trade will start detouring A. Therefore, the overall revenue (solid black) is retrieved at a tariff marginally below one. Note that the revenue function is not differentiable.*

detours the same set of countries, $\{i\}$ in our case, as

$$h^j_{\{i\}} = \min_{r \in W_{wj}, \{i\} \not\subset r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) - \min_{r \in W_{wj}, \{i\} \cap r} \left(\sum_{n=2}^{|r|} \left(\phi_{r_{(n-1)} r_n} \right) \right) > 0 \tag{9}$$

This yields

$$h^j_{\{i\}} = \phi_{wj} - (\phi_{wi} + \phi_{ij}) > 0.$$

As in figure 3, the revenue of i is discontinuous at $h^j_{\{i\}}$. Any higher tariff implies the loss of transit trade to j. Country i is confronted with a binary decision problem $d_{ijg} \in \{0, 1\}$ and compares the revenue from setting $t_{ig} \leq h^j_{\{i\}}$, which would allow imports from j to transit i ($d_{ijg} = 1$), or setting t_{ig} above $h^j_{\{i\}}$ and force traders to detour i ($d_{ijg} = 0$). The maximization problem of i can hence be spelled out as

$$R_i = \max_{t_i, d_{ij} \in \{0,1\}} \left(t_i (M_i(t_i) + d_{ij} M_j(t_i)) \right) \qquad \text{s.t. } d_{ij} t_i \leq h^j_{\{i\}}. \tag{10}$$

Proposition 1. *Countries may have to give up revenue from transit trade when setting the island-tariff*

Proof. If country i forfeits transit trade to j, the tariff rate t_i is retrieved as in the island case, $t_i = t_i^I$. Consider the tariff that country i can set allowing for transit trade to j, t_i^j. The condition $d_{ij} t_i \leq h^j_{\{i\}}$ can be either binding or not binding, and $t_i^j \leq h^j_{\{i\}}$. Consider the case that the condition is not binding, e.g. $h^j_{\{i\}} \to \infty$. Country i would only find this beneficial iff

$$t^j_{ig} \left(M_i \left(t_i^j \right) + M_j \left(t_i^j \right) \right) \geq t_i^I \left(M_i \left(t_i^I \right) \right) \tag{11}$$

Consider the case in which this tariff would be too high too allow for transit. If country i wants to allow transit from j, it has to set $h^j_{\{i\}}$. Else, if this tariff is lower than the detour costs anyway, country i can set the tariff as in the surrounded case,

$$t_i^j = \begin{cases} [t_i^j \mid h^j_{\{i\}} \to \infty] & \text{if } [t_i^j \mid \phi_w \to \infty] \leq h^j_{\{i\}} \\ h^j_{\{i\}} & \text{else} \end{cases} \tag{12}$$

Monotonicity of demand for each of the countries w.r.t. tariffs imposes that this is optimal. The binary decision of allowing for transits to j is therefore expressed as

$$d_{ij} = \begin{cases} 1 & \text{if } t_i^j \left(M_i \left(t_i^j \right) + M_j \left(t_i^j \right) \right) \geq t_i^I \left(M_i \left(t_i^I \right) \right) \\ 0 & \text{else} \end{cases} \tag{13}$$

□

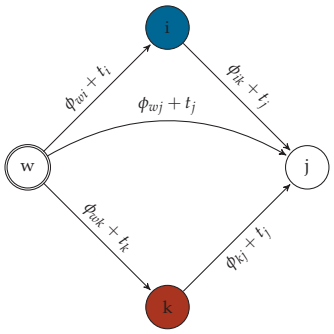

Figure 4: *Given that the direct route from w to j is very expensive, i and k compete over transits*

(iii) Competition Between two Upstream Countries

This trade-off, which a potential transit country faces changes as we introduce a third country k that can allow access to world markets to j.

Consider k as our third country, as in figure 4. There are three routes to j, $W_{wj} = \{(w,j),(w,i,j),(w,k,j)\}$. Let the cheapest route go via i, the second cheapest route goes via k, and the most expensive route is the direct one. The cheapest route to j therefore depends on parameters,

$$min(cost_{wk}) = \begin{cases} \phi_{wi} + \phi_{ij} + t_i + t_j & \text{(cheapest route via i)} \\ \phi_{wi} + \phi_{ij} + h^j_{\{i\}} + t_k + t_j & \text{(second cheapest, detour i, via k)} \cdot \\ \phi_{wi} + \phi_{ij} + h^j_{\{i,k\}} + t_j & \text{(detour both i and j)} \end{cases} \tag{14}$$

Proposition 2. *Two countries can engage in Bertrand competition over the least cost routes between world market and a third country. The decision whether any country will find it beneficial to engage in competition depends on their relative size and position*

Proof. Consider the case that D_k is sufficiently large and transport costs ϕ_{ij} and ϕ_{kj} are sufficiently low, so that both i and k would find it beneficial to allow for transit trade to j. As long as t_i is below $h^j_{\{i\}}$, country k would have to set a negative tariff rate (which cannot be revenue-maximizing). Additionally, country i can safely increase its tariff above the level of $h^j_{\{i\}}$ to the point it expects k to

lower its tariff rate to attract the transit. The maximization is given by

$$R_{ig} = \max_{t_i, d_{ik} \in \{0,1\}} \left(t_i^j (M_i \left(t_i^j\right) + d_{ij} M_j \left(t_i^j\right))\right) \text{ s.t. } d_{ij} t_i^j \leq h_{\{i\}} + t_k^j \tag{15}$$

while i has to be aware that j will decrease its tariff rate below the island tariff to attract transit if this comes with a positive revenue effect, so that

$$t_j = \begin{cases} t_j^I & \text{if } \left(t_i - h_{\{i\}}^k\right) \left(M_j \left(t_i - h_{\{i\}}^k\right) + M_k \left(t_i - h_{\{i\}}^k\right)\right) < M_j \left(t_j^I\right) \\ \left(t_i - h_{\{i\}}^k\right) & \text{else} \end{cases} \tag{16}$$

which in turn means that i can safely raise its tariff until it expects k to be indifferent between $R_k \left(t_k^I\right)$ and $R_k \left(t_k^j\right)$. □

3. *Customs Unions*

Figure 5: *A potential customs union between i and j would eliminate tariffs between i and j*

Consider now a situation with many countries, and that countries are allowed to form customs unions. Following Viner (1950), a customs union is a set of countries U that agree on a single tariff rate (for imports and transits) t_U, distribute the tariff revenues according to a distribution mechanism so that any member i would receive a share π_i^u of R_U, and abolish internal borders. The rules of this unions are given and non-negotiable, and defined as followed.

Country i from figure 5 faces a binary decision γ_i^u between its independent revenue and its share in union revenue Π_{iU}

$$\max_{\gamma_i^u \in \{0,1\}} \left(\left(1 - \gamma_i^u\right) R_i + \gamma_i^u \pi_i^U R_u\right) \tag{17}$$

(i) Benefits of a Customs Union

Conditional on geography, the foundation of a customs union can create revenues otherwise wasted due to multiple marginalization.

Proposition 3. *The decision to join a customs union depends on the world market price of the good (it has to be high enough), relative size (countries have to be sufficiency unequal), relative position (the union must have a sufficiently better position than the independent country), the slope of the demand curve (which has to be flat enough), the relative level of physical transport costs (which have to be low enough), and the absolute level of transport costs (they have to be either sufficiently large or sufficiently small, as this relationship is convex).*

Proof. We have to show under which conditions the sum of independent revenues is smaller than the revenues of the customs union,

$$R_U - \left(R_i + R_j\right) \geq 0.$$

Regarding the customs union, we retrieve the tariff charged analogous to the independent maximization,

$$\frac{\partial \left[t_u \left(D_i - a\left(p_w + \phi_{wi} + t_u\right) + D_j - a\left(p_w + \phi_{wi} + t_u + \phi_{ij}\right)\right)\right]}{\partial t_u}$$

$$\Leftrightarrow t_u = \frac{D_i - a\left(p_w + \phi_{wi}\right) + D_j - a\left(p_w + \phi_{wi} + \phi_{ij}\right)}{4a}. \quad (18)$$

Import volume M_u can then be calculated by solving equations 1–3 in reverse order. Multiplying this volume with t_u as in equation 4, yields the union's revenues R_u. We set up the revenue function of independent j by inserting equation 8 into equation 6 to retrieve t_j, solve for M_j from equations 1–3 (as pictured in figure 2), and insert t_{ig}^{j} and M_j into equation 4. This yields optimal t_j, the resulting imports M_j, and finally R_j. Revenue R_i can then be calculated by inserting the tariff from 8, transit M_j, and imports M_i (from equations 1–3 reversely) into the revenue equation 10.

We spare the reader the complete formula for the customs union effect[11] and rather employ some comparative statics to understand it. To understand the effect of relative size (relative demand), we express D_j in terms of D_i. This yields $D_j = D_i - \delta$, while $\delta \lesseqgtr 0$ is just the difference, so that δ can proxy relative size. Replace $D_i - \delta$, and consider first and second derivatives of the customs union effect w.r.t. δ. This shows that the relationship between the customs union effect and the relative size is convex. With increasing inequality in sizes, the customs union effect becomes positive.

Focus on the effect of physical transport costs, in absolute and relative terms. Assume a negative shock on the absolute level of physical transport cost, e.g. through technological progress. Replace ϕ_{wi} by $\phi_{wi} - \tau$, and ϕ_{ij} by $\phi_{ij} - \tau$. First and second derivative w.r.t. τ reveal a convex link.

The first and second derivative of the customs union effect w.r.t. ϕ_{ij} yield a concave function. The effect is smallest at either extremely low or extremely high costs ϕ_{ij}. Consider the extreme case of no physical transport costs, then there would be no gain from cooperation. As physical transport costs approach infinity, shortest paths and detours converge in relative terms.

□

(ii) Negative Effects of a Customs Union for an Upstream Country

States such as the free cities of Hamburg and Bremen, Germany's trade entrepôts, remained outside of the customs union even after the foundation of the German empire in 1871, almost half a century after other German states had joined into a customs union. The prime reason is that revenues within the German customs union were distributed relative to population shares, neglecting their geographic position.

Proposition 4. *A country can loose from joining a customs union, depending on its promised share of the unions revenue (if too small), market size relative to other members (if too different in sizes), relative geographic position (if too advantageous before joining), world market prices (if too high), and level of physical transport costs (if too high)*

Proof. A customs union $u = \{i, j\}$ would distribute revenues as follows

[11] Please find the algebra for all revenues, and the following comparative statics, in the technical appendix.

$$\pi_i^u = \frac{D_i}{D_i + D_j}.$$

Compare figures 2 and 5. Consider the case in which state i has a strong geographic advantage over j, so that $h_{\{i\}} > t_{ig}^j$ (equations 11 and 8). When deciding over joining the union, i faces the trade-off (equation 17),

$$\max_{\gamma_i^u \in \{0,1\}} \left((1 - \gamma_i^u) R_{ig} + \gamma_i^u \frac{D_i}{D_i + D_j} R_u \right) \tag{19}$$

We set up the revenue function[12] from independent i and the union u, and undertake some comparative statics as in proposition 3. The intuition is the following. The country gives up its geographic position, and control over transit trade. It receives a share of union's revenues that is independent of the income when independent, as transit trade is neglected. The control the country gives up when joining is higher when physical transport costs (hence the detour costs) are high so that transport costs represent a considerable share of the price to the consumer.

□

(iii) Why Countries Join a Customs Union

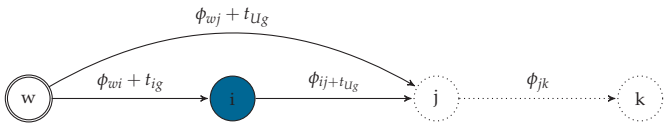

Figure 6: *Countries i faces a trade-off between control and customs union-effect*

We established that the decision whether to join a customs union depends on the sizes of customs union effects and the control over trade routes countries give up.

Theorem. *Revenue-maximizing countries trade off geography-induced positive customs union effects from joining a customs union with their loss of control over a advantageous geographic position.*

[12] Please find the algebra in the appendix.

Proof. Consider figure 6. There exists a customs union $U = \{j, k\}$. Country i can decide whether to form a customs union $U' = \{i, j, k\}$. From equation 17 it follows that i faces a binary decision between the revenue from staying independent, R_i, and it's exogenous determined share $\pi_i^{U'}$ of the customs union's revenue $\pi_i^{U'} R_{U'}$.

We established that there is a positive effect from joining the customs union (proposition 3). In contrast, if a country is in total control of access to world markets, there is a loss from joining the customs union 4. As outlined in the two country case, there is also Bertrand competition over routes that limits the tariff rates.

With increasing world market price, the network effect grows faster than the control effect. To proof this, set up first derivative of network effect and the control effect w.r.t p_w. The first derivative of the difference between customs union effect and control effect can never be negative under the assumption that all variables are positive and there is demand in all countries. Therefore with increasing world market price, the union becomes more attractive. □

D. EMPIRICAL STRATEGY

We cannot match the trade flows and trade costs of all Central European countries. The main problem is the lack of data. The German state archive in Berlin has official tariff on many German states on file, as exchanging such information was part of diplomatic exchange. However, the majority of political trade costs has never been recorded. The German states were just in the making of the tariff system, so that various systems of tariff collection were applied simultaneously. For example, the Northern harbor cities, like Bremen and Hamburg, for many years had an official tariff rate of zero. It is of course wrong to assume this implied the absence of political costs. Handling fees and non-monetary regulations created state revenue paid for by consumers in the hinterland. Other examples include Central German states' staple rights, road and river tolls, which added to the notoriously complicated tariff landscape.

We face the same data restriction concerning trade flows. Important trade hubs, such as Hamburg and Bremen did not bilateral trade data until the 1890's, when their statistical offices have been

integrated into Imperial Germany (Onishi, 1973). There are indeed some exemplary route maps and notes kept by traders of the time that allow us understanding the cost structure of trading in our time period. We can such such sources as anecdotal evidence that traders were indeed minimizing trade costs as assumed in the theoretical model. But we cannot aggregate this to actual trade flows.

We can also not use the available data of single countries and interpolate for all others. Any small change in the transport framework can change the outcome for all other states. For example, small changes in the tariff of a single central country can have consequences for another country hundreds of kilometers away due to re-routing. Any missing data point, any wrong assumption in reconstruction of such data can destroy the whole picture. Second, tariff rates, trade flows, and even import figures are endogenous outcomes of our model, and have to be interpreted simultaneously.

The only truly exogenous variables we have in our model is the geography of the states, including their borders, rivers, roads (which are exogenous in our small time window), and physical transport costs (which are exogenous under the assumption of perfectly competitive transport- and retail-sectors), and consumer's preferences and demand elasticity. It is safe to concentrate on those goods that created the bulk of the tariff revenue (see Onishi (1973)) and did not have a significant domestic competition: Sugar, coffee, and alcohol. For these goods, we fitted linear demand curves. For these goods, preferences were common, and their consumption was not restricted to elites but already standard in large shares of population Ferber (1829). All these parameters (see table 2) can be used to quantify the environment in which state rulers set revenue-maximizing tariff rates. The outcome would be the tariff revenue that all states could have gained from tariffs, given their geography. If these figures can explain why some states joined the Zollverein either sooner or later, then we can simulate counterfactual changes in the geography to predict their consequences.

Physical transport costs ϕ are calculated using GIS, employing maps by Kunz and Zipf (2008), per-kilometer rates from Sombart (1902) and the algorithm by Dijkstra (1959) [13].

We calculate the demand for any region j using table 2. We weighted the price of coffee, sugar, and

[13]We are grateful for the contributors of the free and open source projects PostgreSQL (postgresql.com), PostGIS(postgis.org), PgRouting (pgrouting.org), and QGIS (qgis.com), which were used exclusively.

Table 2: *Parametrization of the Simulation*

Parameter	Letter	Description	Source
World market price	p_w	Average London prices 1822–1831[a]	Clark (2010)
Market size	D	Population data 1820[b]	Kunz and Zipf (2008)
Elasticity of demand	η	Pfister (2012) reports an elasticity of -0.5 using Hamburg prices for 1736-1798. Ewert and Pfister (2017) estimate a lower elasticity for the 19th century. Elasticity is therefore assumed to be -0.85.	Pfister (2012)and Ewert and Pfister (2017)
Physical transport costs	ϕ	GIS map of central Europe 1820[c], including harbors, rivers, roads, and country shapes. Per-kilometer rates[d] are constant per weight, discriminated by transport mode. These are (in the order of increasing per-kilometer price) river transport with the stream, sea freight, river transport against the stream, land transport on paved roads, and land transport elsewhere. Switching transport modes is possible anywhere they cross. Transportation costs are independent of the quality and/or category of the good. The transportation costs of a liter is assumed to correspond to that of one kilogram. Gross weight equals tare weight.	GIS maps from Kunz and Zipf (2008) and own maps. Per-kilometer rates and transshipment costs from Sombart (1902)

[a] Values were standardized using reported prices in grams of silver.

[b] To account for the variation in the size of states, larger territorial states are split into their first geographical subdivision to analyze demand: Prussia (9 parts), Austria Hungary (9), Bavaria (8), Hanover (7), France (6), Baden (6), Saxony (5) Wurttemberg (4), Hesse-Darmstadt (3), Saxony-Weimar-Eisenach (2), Oldenburg (2), Saxony-Coburg-Saalfeld (2), and Sachsen-Gotha-Altenburg (2). A region's demand is assumed to be concentrated in it's capital.

[c] Rivers were turned into floating direction. Roads were added from own maps. Sea harbors were included.

[d] Values were converted using currency's silver content.

alcoholic beverages, using per-capita consumption in Prussia 1820–1830 from Dieterici (1846) and Ferber (1829). Price data uses the exogenous London price data from Clark (2010). We assume that all imports that states use show an elasticity of -0.85. The price consumers in j have to pay for a kilogram of this import basket p_w, the physical transport costs ϕ on the least cost path P_{wj} and the sum of the tariffs t of all states on this least cost path S_P. Demand elasticity is constant and given by ϵ. Assuming there is only that one bundle of import goods, any consumer would have a potential demand of DPC_j.

$$DPC_j = \beta(p_w + \phi_{P_{wj}} + \sum_{i \in S_P} t_i)^{\epsilon} \tag{20}$$

To retrieve the regions demand, we multiply by its population pop, assuming uniform income

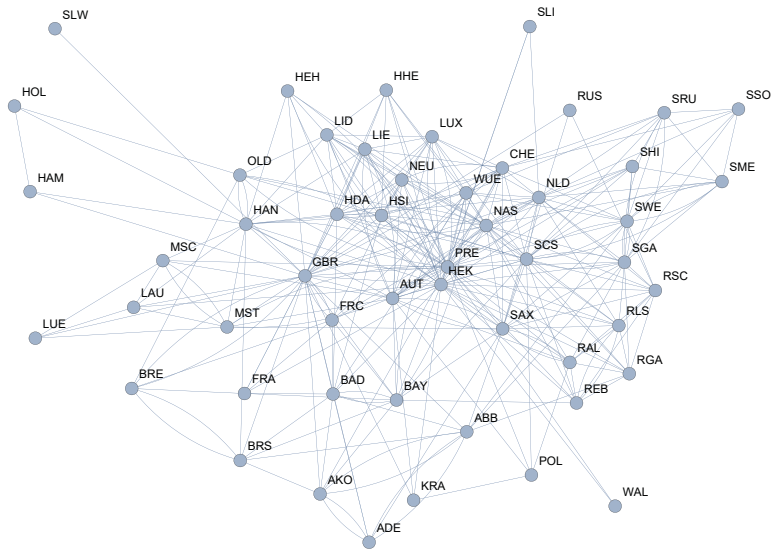

Figure 7: *Network graph of 1820 Germany and surrounding countries. Note the centrality of Prussia and the Hessian states. Abbreviations: ABB=Anhalt-Bernburg, ADE=Anhalt-Dessau, AKO=Anhalt-Köthen, AUT=Austria, BAD=Baden, BAY=Bavaria, BRE=Bremen, BRS=Brunswick, CHE=Switzerland, FRA=Frankfurt, FRC=France, GBR=Great Britain, HAM=Hamburg, HAN=Hanover, HDA=Hesse-Darmstadt, HEH=Hessn-Homburg, HEK=Hesse-Kassel, HHE=Hohenzollern-Hechingen, HOL=Holstein, HSI=Hohenzollern-Sigmaringen, KRA=Cracow, LAU=Lauenburg, LID=Lippe-Detmold, LIE=Liechtenstein, LUE=Luebeck, LUX=Luxemburg, MSC=Mecklenburg-Schwerin, MST=Mecklenburg-Strelitz, NAS=Nassau, NEU=Neuenburg (Neuchâtel), NLD=Netherlands, OLD=Oldenburg, POL=Poland, PRE=Prussia, RAL=Reuß Greiz, REB=Reuß-Ebersdorf, RGA=Reuß-Gera, RLS=Reuß-Lobenstein, RSC=Reuß-Schleiz, RUS=Russia, SAX=Saxony, SCS=Saxony-Coburg-Saalfeld, SGA=Saxony-Gotha-Altenburg, SHI=Saxony-Hildburghausen, SLI=Schaumburg-Lippe, SLW=Schleswig, SME=Saxony-Meiningen, SRU=Schwarzburg-Rudolstadt, SSO=Schwarzburg-Sondershausen, SWE=Saxony-Weimar-Eisenach, WAL=Waldeck, WUE=Wurttemberg.*

distribution. In order to allow for an optimal tariff below infinity, we enforce a choke quantity of DPC_C below the regions demand falls to zero (the intuition being it does not pay to ship anything to the region due to setup costs).

$$D_j = \begin{cases} pop_j DPC_j & \text{if } DPC_j > DPC_C \\ 0 & \text{else} \end{cases} \tag{21}$$

This demand function is known to all states, so is geography. While we take all variables except the quantity at which demand is choked DPC_C from the literature in table 2, this parameter needs

careful examination. A prohibitively high quantity of necessary imports would reduce the number of states that can generate any tariff revenue. A two low number generates unrealistically high tariff rates for some states. States which mostly generate income from import tariffs would find it beneficial to raise their tariff rate further since their own population cannot react to an increase in the tariff except by reducing the quantity of imports consumed. Therefore, we can assess the quality of the assumed choke quantity best looking at states without transit revenues.

To initiate a simulation, the following steps are necessary:

1. Load the geography of states at the historical period in question given their positions, sizes, and transport networks as given in table 2.
2. Group all states that should form one or many customs unions. These states will then take part the simulation as a single player, and can set only one tariff. All other states are independent players.
3. Initiate all tariffs with zero.

To simulate the fact that all states react to all other states' tariffs, as their revenues and their possible revenues might be affected, we run a large number of rounds with the following steps.

1. Shuffle the order of players so that all players have exactly one turn. Start with the first player in line.
2. Retrieve the current players tariff and save it to t. Solve for the demand of all regions that would trade via the current player given all tariffs of other states do not change, and given t. Calculate the player's revenue. Store this result in a.
3. Generate a small random number $r > 0$.
4. Repeat step 2, but now given that the player sets tariff $min(0, t - r)$. Store the resulting revenue in b.
5. Repeat step 2, given the player sets tariff $t + r$. Anticipate that an increase in the current player's tariff rate might motivate other players to reduce their tariff in the next round by assuming that this other player would immediately do so. Store the resulting revenue in c.

6. Choose the maximum of a, b, and c, and inform everyone that the current player's new tariff is unchanged if the maximum is a, $min(0, t - r)$ if the maximum is b, or $t + r$ if the maximum is c.

7. The next player starts with step 3. If all players had their turn, start a new round with step 1.

The outcome of the simulation yields an approximation of the optimal tariffs and the overall tariff revenue from the three goods for all the states and simulated unions S, given that the number of rounds is sufficient.

Introducing some randomness into the decision room of states (step 3) comes with several advantages for the simulation. First, concerning the number of steps we have to simulate. An alternative would be to name a discrete accuracy for the simulation. Let's say we would like the optimal tariff level to be accurate at a tenth of a gram of silver. Due to the kinks in the revenue function, we cannot stop the algorithm, for example if revenue starts decreasing while trying the effect for stepwise increasing of the tariff. This simulation would therefore give us a very exact, but incredible computer intensive solution. Using random steps, given the amount of steps is sufficiently large, the players make rather large changes in the beginning but the number of adjustments slows down (as r might be to to large by chance) until a stable solution is reached. Secondly, and most importantly, this randomness reflects the nature of the historical process. Dieterici (1846) reports that tariff adjustments were agreed upon and announced in rather small steps. Tax administration had a general idea if the current tariff was rather to high or to low or should not be adjusted, but they could not try out their decision to know exactly which changes their decisions would create. We argue that states, like the modern Federal Reserve most of the times, adjusts their decision variable in steps of equal size, and it is therefore reasonable to restrict their decision space to three options. Third, it would be unrealistic to assume, given different local currencies, and weights, that all states would use the same steps for the optimization.

The outcome of this simulation is a tariff that all states would set, their revenue, and demand by their respective consumers.

E. RESULTS

In this section we use our calibrated model to replicate the course of events that led to the formation of the Zollverein in 1833. Our model implies that any change in tariffs of any change will affect all others. To get around this problem of simultaneity, we proceed under the assumption that Prussia as by far the largest state was an agenda setter in the spirit of Ploeckl (2010). Instead of exploring all possible strategic interactions we limit our attention to the observed chain of events and several alternative options as discussed in the contemporary debate. The results are shown in table 3.

We assume for all states follow only the goal of tariff revenues maximization over an infinite time horizon that is captured in the model, except Prussia and Bavaria. The Prussian finance minister Motz, in office since 1825, saw as the main long-run challenge of Prussian finance to connect the two separate territories. The expected income of achieving this connection, due to a more efficient provision of public goods and also by combination of natural resources to foster development, in his eyes justified short run reductions in tariff revenue, if not too substantial. The same was true for Bavaria, which after the acquisition of the *Rheinpfalz*, which was also separated from the core, most prominently by Hesse-Darmstadt (see figure 1).

We start with the situation in late 1827, with a Prussian Customs unions that included the major enclaves. As shown in table 3, column 1, the Prussian Customs Unions generates substantial net-revenue per capita, higher than those in Bavaria or Wurttemberg, but lower than those in Hesse-Cassel, which benefits from its excellent location as a transit state between the eastern and western parts of Prussia and between Southern and Northern Germany, as the Rhine was still blocked due to high customs. Column 2 shows the situation in January 1828, after the Kingdom of Wurttemberg and the Kingdom of Bavaria had agreed to form the Southern German customs union, the first modern customs union in Germany, where two sovereign partners agreed to set a common external tariff. Apparently, this union was more beneficial to Wurttemberg than to Bavaria, reflected in the fact that the initiative to this treaty came from Wurttemberg (Hahn, 1984, p. 41). Bavaria was eager to integrate the small state of Hesse-Darmstadt into this Southern-German customs

Table 3: *Simulated tariff revenues of selected states per capita and the historic sequence of central decisions to join the German Zollverein*

	Late 1827: Prussian CU including enclaves	**January 1828**: Prussian CU with Southern German CU	**Counterfactual: February 1828**: Hesse-Darmstadt joins Prussian Southern CU	**February 1828**: Hesse-Darmstadt joins Prussian CU	**May 1829**: Southern CU signs preliminary agreement with Prussian CU	**March 1831**: formation of Belgium and Mainz Convention opens the Rhine, assumption: Southern CU stay out	**March 1831**: formation of Belgium and Mainz Convention opens the Rhine, assumption: Southern CU joins	**August 1831**: Hesse-Cassel joins Prussian CU, assumption: Southern CU stay out	**August 1831**: Hesse-Cassel joins Prussian CU, assumption: Southern CU joins
Prussian CU	40.78	44.17	49.32	42.03	27.15	34.49	31.02	38.33	22.19
Bavaria	14.34	7.31	9.76	9.84	27.15	-0.79	31.02	3.28	22.19
Wurttemberg	-3.85	7.31	9.76	9.84	27.15	-0.79	31.02	3.28	22.19
Hesse-Darmstadt	26.29	24.15	9.76	42.03	27.15	34.49	31.02	38.33	22.19
Hesse-Cassel	74.77	42.17	76.09	82.78	3.5	-8.05	-7.55	38.33	22.19

These simulations are based upon the GIS maps of the European geography and calibrated demand functions as depicted in table 2. The changes due to the Belgian revolution are included by replacing the shapes of the Netherlands 1820 by the Netherlands 1831 and Belgium 1831, each provided with population data of 1831.

union, which was the missing land-bridge to the Bavarian Palatinate (Rheinpfalz). We see that this customs union was slightly harmful to both Hessian states, as it limited their bargaining power with respect to a now larger united hinterland. But Hesse-Darmstadt was more oriented towards Prussia, as its main markets were in the Prussian Rhineland. Attempts by Hesse-Darmstadt to find a customs agreement with Prussia in earlier years had been rejected. Prussia had been so far reluctant to make any concessions to the tiny Hessian state, because it expected to benefit very little from this. The Prussian position until 1827 had been that any negotiations would have to include the larger Hesse-Cassel as well. This was because the territory of the latter provided the missing land-connection between the eastern parts of Prussia and its western provinces of Rhineland and Westphalia. Consider columns 3 and 4 in table 3: in our simulation Hesse-Darmstadt benefitted from a customs union with Prussia but not from a customs union with the Southern Zollverein. In contrast, it would have been beneficial for the latter. Moreover, a comparison between column 2 and column 4 shows that the treaty with Hesse-Darmstadt was not beneficial for Prussia. Why then, did Prussia agree? A main strategic aim of Prussia was to get a land-bridge between its eastern and western parts. The Hessian states, and notably Hesse-Cassel were the missing link. After the formation of the Southern Customs Union, Prussia immediately saw the possibility to exert pressure on Hesse-Cassel via and union with Hesse-Darmstadt and an agreement with the southern states. But this was possible only if Prussia could signal to Bavaria and Wurttemberg that a customs union would not put their sovereignty at risk. The treaty with Hesse-Darmstadt signed in February 1828 was remarkable in the sense that the small Hessian state was treated as an equal partner by Prussia. Notably, it was agreed that all tariffs required the consent of both partners. At the same time, the southern states realized that they could benefit hugely from a union with Prussia, given their unfavorable geography. In May 1829, Bavaria and Wurttemberg signed an agreement with the now enlarged Prusian customs union a preliminary treaty to prepare their future merger. Comparing columns 4 and 5 we see that this had the effect on Hesse-Cassel that Prussia had hoped for: the Hessian state would have suffered a very substantial decline in tariff income if both customs unions would have merged. But the negotiations continued, and the electorate of Cassel Wilhelm II tried everything to avoid a customs union with Prussia. In September 1828 he had formed an agreement with Saxony, Hanover and several other states to fend off what was seen as attempts of Prussian expansions with the *Mitteldeutscher Handelsverein*. At the

same time, the economic situation of Hesse-Cassel deteriorated and many citizens demanded a change in policy and an agreement with Prussia. In September 1830 enraged citizens destroyed customs offices in Hesse-Cassel (Hahn, 1984, p. 60). Maybe more importantly, the situation of the Rhine changed fundamentally. Since the start of the Belgian revolution, the Netherlands had been under pressure to give in to long-standing demands from upstream states, notably Prussia, for lower tariffs and a liberalization of shipping rules. The independence of Belgium with the London Conference in December 1830 and with it the emergence of a trade competition for the port of Rotterdam. After many years of negotiations, the Netherlands gave in and the riparian states on the Rhine signed in March 1831 the Mainz Convention to liberalize trade on the river. This as the last blow for Hesse-Cassel, as it essentially eliminated overland transit as its main source of income. In August 1831 Hesse-Cassel signed an agreement to join the Prussian customs union, in Electorate Wilhelm II resigned in favor of his son Frederick William I. in September 1831. Consider columns 5, 6 and 7 of table 3. After Hesse-Darmstadt had joined the Prussian Customs union and the Southern Union had signed an agreement to join later, Hesse-Cassel had already suffered a decline in tariff-revenue. This turned negative in our simulation after the liberalization of the Rhine, and this with or without a de facto merger between the Prussian and the Southern Customs Union. Hence, after 1831 Prussia was at the height of its influence. It finally exerted control over large parts of the Elbe and the Rhine and could use it to enforce the unification of its two territorial parts in terms of tariff policy. Moreover, it now had substantial influence over Southern Germany and used it to create the Zollverein in 1833 in separate negotiations with the Southern Customs Union, with Saxony and with the Thuringian states. We see from a comparison of columns 8 and 9 that the Zollverein was not immediately beneficial for Prussia, but it was for Southern Germany and Hesse-Cassel. However, by then the expectation in Prussia was that an enlarged market would facilitate an expansion of economic activity and trade that would pay of in the course of several

years. Data from Onishi (1973) indeed suggests that this was the case.

Table 4: *Simulated tariff revenues of selected states per capita given a counterfactual geography of a Prussia that includes the whole of the Kingdom of Saxony, but excludes the Rhine Province and Westphalia, which act as an independent territory*

	Independent States of cf Prussia, Rhineland-Westphalia, Hesse, Southern CU	Merger between Prussia, Hessian states and Southern CU, excl. Rhineland	Formation of a West-German CU, excluding Prussia	Formation of a "Zollverein" between cf Prussia, Rhineland-Westphalia, Hesse, Southern CU
Prussian CU (incl. Saxony)	48.45	22.98	56.85	18.43
Bavaria	8.45	22.98	13.2	18.43
Wurttemberg	8.45	22.98	13.2	18.43
Hesse-Darmstadt	92.29	22.98	13.2	18.43
Hesse-Cassel	100.7	22.98	13.2	18.43
Rhineland-Westphalia	37.68	33.01	13.2	18.43

These simulations are based upon the GIS maps of the European geography and calibrated demand functions as depicted in table 2. The counterfactual is based only upon relabeling of terroritories in the factual historic borders. The two Prussian provinces *Rheinprovinz* and *Westfalen* where relabeled as not part of the Prussian state but act as an independent player. The kingdom of Saxony was relabeled as part of Prussia. The changes due to the Belgian revolution are included by replacing the shapes of the Netherlands 1820 by the Netherlands 1831 and Belgium 1831, each provided with population data of 1831.

How important was the westward expansion of Prussia as it was enforced by Britain in 1815? Consider the results in table 4. We focus our attention to four cases, each under the assumption of a counterfactual political geography, where Prussia is extended southwards to include the entire kingdom of Saxony, while Rhineland-Westfalia constitutes a new sovereign political entity. Moreover, to ease comparisons with the results above, we only consider situations where a Southern Customs

Union has formed and with an independent Belgian state that competes with the Netherlands for trade, thereby limiting tariffs on the Rhine trade.

The main finding from table 4 is that all relevant states are better off if they set their tariffs independently, except the Southern German Customs Union, due to their hinterland position. Comparing col. 1 and 2 we see that a sovereign Rhineland-Westphalia would have had little incentive to join a customs union around Prussia that would include the Hessian states and the Southern German Customs Union. But such a union would likely not have formed in the first place, because the Hessian states had no incentive to join, nor would a counterfactual Prussia have had an interest in such an arrangement. More surprisingly, a West-German customs union similar to the boundaries of a West-German state as it formed after 1945 would also rather not have formed, unless the northern states, notably Bremen and Hanover would have been part of this (not shown here). Finally, a counterfactual Zollverein that would merge the tariff systems of Prussia, the Hessian states, the Southern customs union and a sovereign Rhinleland-Westphalia would have been only for southern Germany attractive, not for anyone else. To summarize, under a counterfactual geography, the most likely outcome would have been a landscape of several smaller customs unions around a Prussian state including Saxony, possibly with a Southern German Customs Union but assuming an independent state on the Rhine and independent Hessian states. Without the westward expansion of Prussia, it would have been less attractive and more difficult for Prussia to use tariff policy as a means of increasing its political influence on states in central and southern Germany. Put differently, we conclude that Britain's strategy to install Prussia as a watchdog on the Rhine to keep France and Russia out of Germany indeed had a remarkable side-effect: unintentionally, Britain put Prussia into a position that it could force other states into an enlarged customs union around Prussia, the Zollverein. Indeed, Britain helped to unify Germany.

F. CONCLUSION

In this paper we considered the factors behind the formation of the German Zollverein as an example of a customs union, and thus endogenous borders. We have argued that the rise of Prussia to dominate German tariff policy can be traced back to a change in "second nature" geography,

namely the redrawing of the European map at the Congress of Vienna in 1814/15. Due to the intervention of Britain, Prussia gained large territories in the West. While this was against Prussia's intention, who wanted to gain the rich and densely populated Kingdom of Saxony, this had far-reaching consequences as Prussia was now in control of a large part of Germany's trade routes. Over time, for more and more states the gains from cooperation with Prussia started to outweigh the costs of losing sovereignty. Our argument is closely related to the literature on the size of nations following Alesina and Spolaore (1997) and Bolton and Roland (1997), who emphasize a trade-off between benefits of cooperation from economies of scale and the costs of loosing political control. We argue that a change in borders can trigger a cascade of changes in both dimensions. The intuition for this result was a basic trade-off between prospective gains from joining a large customs union with network effect and control over revenues. In 1815 all the German states that still existed as sovereign entities after the Napoleonic wars were in financial difficulties, including Prussia. All of them attempted to increase their state revenues, reduce costs, while keeping as much of their political sovereignty as they could. Notably they were eager to stay in control over their revenue. With the formation of the Prussian Zollverein in 1818 states had to weigh the potential gains from higher tariff revenue net of costs after joining into the Zollverein against the loss of control over these revenues, hence a loss of political sovereignty. The fact that Prussia controlled large parts of the German river system after 1815 considerably reduced the control that other German states had over their own tariff income, because much of their trade had to be routed over Prussian territory. Moreover, after Hesse-Darmstadt decided to join the Zollverein, all other German states are forced to follow suit. We used detailed GIS data on population, state boundaries, infrastructure and transport mode specific transportation costs to calculate first cheapest cost paths and next expected volumes of trade and transit flows between a set of 106 regions across Germany and neighbouring territories. Based on this we calculated expected changes in tariff revenue, tariff collection costs and changes in control over revenue for each sovereign state if he decided to join Prussia into a customs union compared to the situation outside the customs union. We use a calibrated GIS model to test whether these expected changes in revenue and revenue control can explain the pattern of joining decisions and find that this fits the observed data extremely well. Finally, we run a counterfactual using the estimated coefficients together with a counterfactual map of Germany in 1815: would the Zollverein have formed if Prussia would have gained Saxony instead of the Rhineland? We find

very clearly, that the answer is no. While certainly unintended, Britain unified Germany.

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APPENDIX

A. TABLES

Table 5: *Summary statistics of the exercise in chapter "Descriptive evidence"*

	Mean	SD	Min	Max
Transit Through Prussia	.7774498	.4228409	0	1.095041
Distance to Oceans	247.139	129.2661	13.75594	477.2779
Std. Distance to Oceans	0	1	-1.805446	1.780349
Distance to Rivers	20.58066	14.39199	3.113955	78.0745
Std. Distance to Rivers	0	1	-1.213641	3.99485
"Cultural Heritage" FE	17.02128	8.771221	1	32
Absolute Monarchy	.3469388	.4809288	0	1
Constitutional Monarchy	.2857143	.4564355	0	1
Length of Border	984.3847	1546.424	74.10594	9487.874
Std. Length of Border	0	1	-.5886346	5.498807
Area	19183.48	50658.91	105.8058	275099.7
Std. Area	0	1	-.3765908	5.051752
Length of Border By Area	.3229386	.260623	.0183537	1.125486
Std. Length of Border By Area	0	1	-1.16868	3.079344
N	49			

Table 6: *Estimates for per-kilometer freight rates from (Sombart, 1902)*

Type	**Cost [Pf/tkm]**
Country road	120
Paved roads ('Chausee')	30
River, downstream	0.7
River, upstream	1.8
Sea freight	0.95

Hilfsmittel-Erklärung

Alle verwendeten Quellen sind im Text der Essays gekennzeichnet und jeweils am Ende der Arbeiten mit vollumfänglicher Zitierung verzeichnet. Mitarbeit von studentischen Hilfskräften, sowie Fragen und Anregungen von Dritten wurden auf der ersten Seite der jeweiligen Essays namentlich oder durch den Namen der Konferenzen und Seminare, an denen die Arbeiten vorgestellt wurden, gewürdigt.

Das Essay "Lord of the Lemons: Origins and Dynamics of State Capacity" profitierte auch von vier anonymen Rezensenten und wurde einem wissenschaftlichen Lektorat unterzogen. Drei anonyme Rezensionen unterstützten bei der Arbeit an den Essays "Endogenous Geography and the Formation of a Customs Union".

Alle Arbeiten wurden von der Themenfindung bis zu Korrekturen in der Formulierung von meinem Doktorvater Nikolaus Wolf begleitet. Jeder einzelne während der Promotionszeit am Institut für Wirtschaftsgeschichte Beschäftigte und auch jeder Gast hat durch unzählige hilfreiche Diskussionsbeiträge diese Arbeit vorangebracht.

Bei der Erstellung dieser Arbeit sind die Software Eclipse for Java Developers Oxygen, Java 6, Stata 14, R 1.1, RStudio 0.99, PostgreSQL 9.6, PgAdmin III LTS, Postgis 2.2, PGRouting 2.0, QGIS 2.18, Microsoft Office 2013, Notepad++, Texmaker 4.4 sowie LaTeX in der Version 2.ϵ zum Einsatz gekommen. Kamen

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Thilo René Huning
Berlin, im Dezember 2017